# PRACTICAL MASONRY:

OR

## A THEORETICAL AND OPERATIVE TREATISE OF BUILDING;

CONTAINING A

SCIENTIFIC ACCOUNT OF STONES, CLAYS, BRICKS, MORTARS, CEMENTS, FIRE-PLACES, FURNACES, &c.; A DESCRIPTION OF THEIR COMPONENT PARTS, WITH THE MANNER OF PREPARING AND USING THEM;

AND

THE FUNDAMENTAL RULES IN GEOMETRY,

ON

MASONRY AND STONE-CUTTING,

WITH

THEIR APPLICATION TO PRACTICE.



ILLUSTRATED WITH FORTY-FOUR COPPERPLATE ENGRAVINGS.

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# PREFACE.

In preparing this work for the public, it has been the design of the Compiler to avoid prolixity, by the rejection of such things as are already known to the mechanic, and to furnish him with a knowledge of the principles and facts on which he might be supposed to require information.

Most works on this subject set out with a description of all the minutiæ of the art of building; and though they may, perhaps, exhibit something that will be useful to the apprentice, yet they contain much that is of no importance to the practical mechanic; while the price is so much enhanced, that few can well afford to possess them.

As permanency in building seems, at the present day, to be an object more desirable than formerly, it has been thought that a brief account of the nature and qualities of building materials, with a short exposition of their component parts, would not be misplaced in a treatise of this kind. The Compiler flatters himself, that he has, on this head, furnished some information, that will be serviceable not only to the operator but to the proprietor; neither of whom can, with safety, remain unacquainted with the quality of the materials employed.

The best writers on the various subjects treated of in this work have been consulted, and such use made of their labors, by abridging, altering, abstracting, and condensing, as seemed advisable to the Compiler, while he has added much that has been the result of many years of practical experience and personal observation. The latest improvements in building have been noticed and brought to the attention of the reader.

In short, brevity with perspicuity, and utility with cheapness, have been aimed at. How far they have been attained is submitted to the decision of an enlightened and indulgent public.

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# PRACTICAL MASONRY.

## CHAPTER I.

### SECTION I. — Marble.

The class of stones denominated *Calcareous* is exceedingly numerous and abundant in nature. Of these, marble is the most important. It is a granular carbonate of lime, or a compact limestone, varying in color, texture, and hardness. Its structure is both foliated and granular. The grains are of various sizes, from coarse to very fine, sometimes, indeed, so fine that the mass appears almost compact. When these grains are white, and of a moderate size, this mineral strongly resembles *white sugar* in solid masses.

Its fracture is foliated; but the faces of the laminæ, which vary in extent, according to the size of the grains, are sometimes distinguishable only by their glimmering lustre. When the structure is very finely granular, the fracture often becomes a little splintery.

Both its hardness and the cohesion of its grains are somewhat variable. In some cases, its hardness undoubtedly depends on the presence of siliceous particles; indeed, it sometimes gives a few sparks with steel. Its specific gravity usually lies between 2.71 and 2.84, water being 1. That is, water as a standard being taken as a unit, the specific gravity of marble is from $2\frac{71}{100}$ units to $2\frac{84}{100}$ units when compared to water, or about $2\frac{3}{4}$ times greater.

It is more or less translucent, but, in the dark colored varieties, at the edges only. Its color is most commonly white or gray, often snow-white, and sometimes grayish-black. It also presents certain shades of blue, green, red, or yellow. Most frequently the colors are uniform, but sometimes variegated in spots, veins, or clouds, arising from the intermixture of foreign substances.

Marble is essentially *a carbonate of lime*, which is composed of 57 parts of lime and 43 parts of carbonic acid; a little water is usually present. It is soluble in nitric acid; and, by the escape of carbonic acid, more or less effervescence is produced; some varieties, however, effervesce very slowly. Before the blow-pipe it decrepitates, and, if pure carbonate of lime, it is perfectly infusible; but by a strong heat its carbonic acid is driven off, and quicklime, or pure lime, whose taste is well known, remains.

*Marble*, in the strict propriety of the term, should be confined to those varieties of carbonate of lime which are susceptible of a polish; including also some minerals, in which carbonate of lime abounds. But among artists this term is sometimes extended to serpentine, basalt, &c., when polished.

Both granular and compact limestone furnish numerous varieties of marble; but those which belong to the *former* exhibit a more uniform color, are generally susceptible of a higher polish, and are hence most esteemed for statuary and some other purposes. The uniformity of color, so common in primitive marbles, is sometimes interrupted by spots, or veins, or clouds, of different colors, arising from the intermixture of hornblende, serpentine, &c. Among the foreign marbles we may mention: —

The *Carrara Marble.* Found at Carrara, in Tuscany. It was highly esteemed by the ancients, and is at present more employed by the Italian artist than any other kind for statuary, vases, slabs for household furniture, &c. It is very white, sometimes veined with gray, and has a grain considerably fine. In the centre of the blocks of this marble very limpid rock-crystals are found, which are called Carrara diamonds. The average price of this marble is ten or twelve dollars a cubic foot.

The *Luni Marble*, found also in Tuscany, is extremely white, and its grain is a little finer than that of Carrara. Of this marble, it is generally supposed, the famous Apollo Belvidere, in the Vatican at Rome, is made, as well as the Antinoüs of the Capitol, and the Antinoüs in bas-relief in the Napoleon Museum.

The *Parian Marble*, obtained from the islands of Paros, Naxos, &c., in the Archipelago, was much employed by the ancients. It is white, but often with a slight tinge of yellow. Its grains are larger than those of the Carrara marble. The celebrated Venus de Medicis, in the gallery at Florence, is of this marble. It was called by the ancients *Lychnites*, in consequence of its quarries being often worked by the light of a lamp. It is on Parian marble that the celebrated tables at Oxford are inscribed.

The *Pentelic Marble.* From Mount Penteles, near Athens. This marble much resembles the preceding, but is more dense and fine-grained; it sometimes exhibits faint greenish zones, produced by greenish talc, whence the Italian name *Cipilino Statuario.* The principal monuments of Athens were of Pentelic marble, such as the Parthenon, the Propylæa, and the Hippodrome. Among the statues of this marble in the Napoleon Museum, at Paris, are the Torso; a

Bacchus in repose ; a Jason (called Cincinnatus) ; a Paris ; the Discobolus reposing ; the bas-relief known by the name of the Sacrifice; the Throne of Saturn; the Tripod of Apollo; and the two beautiful Athenian inscriptions known by the name of "Nointel Marbles," because M. Nointel caused them to be brought from Athens to Paris in 1672.

*Greek White Marble.* The marble to which the statuaries of Rome give the name of *Marmo Greco* is of a very bright snow-white color, close and fine-grained, and of a hardness which is rather superior to that of other white marbles. It takes a very fine polish. It has been called Corallic marble, from being found near the river Coralus, in Phrygia. According to Pliny, it was found in Asia, in masses of small dimensions; and it is said that a similar kind occurs on Mount Canuto, near Palermo, in Sicily. The Greek marble was obtained from several islands in the Archipelago; such as Scio, Samos, &c. Among the statues of this marble in the Napoleon Museum are a Bacchus, and Zeno, the philosopher.

*Translucid White Marble.* This much resembles Parian marble, but differs from it as being more translucid. There are, at Venice, and several other towns in Lombardy, columns and altars of this marble, the quarries of which are perfectly unknown.

*Flexible White Marble.* It is of a beautiful white color, and fine grain. There are five or six tables of it preserved in the house of the Prince Borghese, at Rome. They were dug up, as the Abbé Fortis was told, in the field of Mondragone. Being set on end they bend, oscillating backward and forward; when laid horizontally, they form a curve.

*White Marble of Mount Hymettus.* This is not a very pure white variety, but inclines a little to gray. Pliny informs us that Lucius Crassus, the orator, was exposed to the sarcasms of Marcus Brutus, because he had adorned his house with six columns, twelve feet high, of the Hymettian marble. The statue of Meleager, in the Napoleon Museum, is of this marble.

These are the chief white marbles which the ancients used for the purposes of architecture and sculpture.

*Black Antique Marble.* (*Nero Antico* of the Italians.) This differs from the modern black marbles by the superior intensity of its color. It has been said that the ancients procured this marble from Greece, but it has been ascertained that quarries of real antique black marble have been rediscovered, which were wrought by the ancients, and of which the remains are still to be seen, at the distance of two leagues from Spa, towards Franchimont, not far from Aix-la-Chapelle. This marble is extremely scarce, and occurs only in wrought pieces.

*Red Antique Marble.* (*Rosso Antico* of the Italians.) This beautiful marble is of a deep blood-red color, here and there with white veins, and, if closely examined, is found to be sprinkled over with minute white dots, as if it were strewed sand. Of this kind is the Egyptian Antinoüs, in the museum at Paris. But the most esteemed variety of Rosso Antico is that of a very deep red, without any veins, such as it is seen in the two antique chairs, and in the bust of an Indian Bacchus in the same museum. The white spots, or points, which are never wanting in the true red antique, distinguish it from others of the same color. It is not known from whence the ancients obtained this marble; the conjecture is that it was brought from Egypt. There is, in the Grimani Palace, at Venice, a colossal statue of Marcus Agrippa, in Rosso Antico, which was formerly preserved in the Panthcon, at Rome.

*Green Antique Marble.* (The *Verde Antico* of the Italians.) This may be considered a kind of breccia, the paste of which is a mixture of talc and limestone; and the dark green fragments are owing to serpentine more or less pure. The Verde Antico of the best quality is that of which the paste is of a grass-green, and the blackish spots are of that variety of serpentine which is called noble serpentine. This marble is much esteemed in commerce, but large pieces of a fine quality are seldom seen. There are four fine columns of it in the Napoleon Museum; but much more beautiful ones are preserved at Parma. This Verde Antico must not be confounded with the marbles known by the names of *Vert-de-mer* or *Vert-d'Egypt.* The real Verde Antico is a breccia, and is never mingled with red spots, while those just mentioned are veined marbles, mixed with a dull red substance, which gives them a brownish hue.

*Red-spotted Green Antique Marble.* Its ground is very dark green, here and there marked with small red and black spots. The quarries of this marble are lost, and it is found only in small pieces, which are made into tablets, &c.

*Leek Marble.* (*Marbre Poireau* of the French lapidaries.) This is a mixture of limestone and a talcose substance of light green, shaded with blackish-green, and related to serpentine. Its texture is filamentose, and, as it were, ligneous; its fragments are splintery. When polished it exhibits long green veins. Like all other talcose marbles, it soon decomposes in the open air. There is a table of it in the Hotel de la Monnoie, at Paris. Its quarries are lost.

*Marble Petit Antique,* of the French lapidaries. It is traversed with white and gray veins, the two colors being disposed in uninterrupted threads; the tables made of this marble are irregularly striped their whole length, which has a very fine effect. It is much esteemed, and only made use of for inlaying ornamental furniture. Its quarries are unknown.

*Yellow Antique Marble.* (*Giallo Antico* of the Italians.) Of this there are three varieties. The first has more or less the color of the yolk of an egg, and is nearly of an uniform tint; the other is marked with black or deep yellow rings, and the last is merely a paler colored variety of the first. These different marbles, for which the Sienna marble is a good substitute, are found only in small detached pieces, and in antique inlaid work. It is in this manner that the two tables of lazulite in the Napoleon Museum are surrounded with a border of the deep yellow variety.

*Grand Antique Marble.* This variety, which is a breccia, containing some shells, consists of large fragments of a black marble united by veins, or lines, of shining white. This superb marble, the quarries of which are lost, is sometimes found in detached pieces and wrought. There are four columns of it in the museum at Paris. A less valuable variety is that in which the spots, instead of being an entire intense black, are of a gray color.

*Antique Cipolin Marble.* Cipolin is a name given to all such marbles as have greenish zones, caused by green talc; their fracture is granular and shining, and shows here and there plates of talc. They are never found to contain marine bodies. The ancients have made frequent use of cipolin. It takes a fine polish, but its ribbon-like stripes always remain dull, and are that part of the marble which first decomposes, when exposed to the open air. There are modern cipolins as fine as that used by the ancients.

*Purple Antique Breccia Marble.* This should not be confounded with African breccia. There is, perhaps, no marble, the color and spots of which are so variable as that of the violet breccia. The following are the chief varieties. The first is that from which the name of the marble is derived; it has a purplish-brown base, in which are imbedded large angular fragments of a light purple color, and others of a white color. This first variety can be employed only in large works, on account of the size of its spots, which are sometimes a foot in diameter. There is a beautiful table of it in the Napoleon Museum. The second variety is, as it were, the miniature of the first; it exhibits the same spots, but within a much narrower compass, so that it may be used for less gigantic works than those for which the other is employed. The third variety is known in commerce by the name of rose-colored marble; in this, the spots, instead of being white and light purple, have a pleasing rose-color. It is scarce and never seen in large pieces. The fourth, which is the

[The term *breccia*, which has often been used in the preceding pages, is applied to an aggregate, composed of angular fragments of the same or different minerals, united by some cement; sometimes, however, a few of the fragments are a little rounded. The different fragments always present a variety of colors. There are several varieties, some of which are susceptible of a fine polish.]

most beautiful, appears, at first view, to be perfectly distinct from the others, but it is, nevertheless, a mere variety of the purple breccia. Its ground is of a yellowish-green color, and the spots, which are of various sizes, are white, green, purplish, and yellow, mottled with red; these various spots are traversed by straight lines of grayish-white color. This fourth variety is very scarce. There are, however, two tables of it at Paris, in the possession of private individuals.

*African Breccia Marble.* Its ground is black, variegated with large fragments of a grayish-white, of a deep red, or of a purplish wine-color; but these latter are always smaller than the former. This is one of the most beautiful marbles existing, and has a supurb effect when accompanied by gilt ornaments. Though rather less vivid in its colors than the preceding violet breccia, it is yet, on the whole, more beautiful. Whether Africa is the part of the world where it is found, as its name implies, is not certain. The pedestal of Venus leaving the Bath, and a large column, both in the Napoleon Museum, are of this marble.

There are other varieties of breccia marble, not differing materially from those already described; they are, many of them, very beautiful, but very scarce, found only in small pieces among the ruins at Rome.

Marbles are found abundantly, and in variety, in all countries. There are many curious varieties in the United States. The chief quarries that have been noticed are the following:—

*Stockbridge and Lanesborough Marble.* In Berkshire county, Massachusetts. Its grain is somewhat coarse, and its color white, sometimes with a slight tinge of blue. A quarry has also been opened of a similar kind of marble, at Pittsfield, in the same county.

*Vermont Marble.* It is found of various qualities, according to Professor Hall, in many places on the west side of the Green Mountains. A few years since, a valuable quarry was found in Middlebury, on Otter Creek, eleven miles above Vergennes. The quarry forms one bank of the creek for several roods, and extends back into the side of a hill, to a distance at present unknown. The stone lies in irregular strata, varying considerably in thickness, but all more or less inclined to the northwest. The marble is of different colors in different parts of the bed. On one side it is of a pure white, and of a quality, if at all, but little inferior to the Italian marble; but this seems to constitute but a small portion of the whole mass. The color that predominates through most parts of the quarry is a gray of different intensities. The marble of both kinds is solid, compact, free from veins of quartz, and susceptible of an excellent polish. A mill of peculiar construction has been erected for the purpose of sawing the stone into slabs. It contains sixty-five saws, which are kept almost in continual operation. During the years of 1809 and 1810 these saws cut out 20,000 feet.

of slabs, and the sales of marble tables, side-boards, tomb-stones, &c., in the same period, amounted to about 11,000 dollars.

Some of the Vermont marbles are as white as the Carrara marble, with a grain intermediate betwen that of the Carrara and Parian marbles.

*New Haven Marble.* The texture of this very beautiful marble is granular, but very fine. Its predominant colors are gray and blue, richly variegated by veins or clouds of white, black, or green; indeed, the green often pervades a large mass. It takes a high polish, and endures the action of fire remarkably well. This marble contains chromate of iron, magnetic oxide of iron, and *serpentine;* hence it resembles the *Vert Antique*, and is, perhaps, the only marble of the kind hitherto discovered in America.

*Thomaston Marble.* From Lincoln county, Maine. It is, in general, fine-grained, and its colors are often richly variegated. Sometimes it is white, or grayish-white, diversified with veins of a different color. But, in the finest pieces, the predominant color is gray, or bluish-gray, interrupted with whitish clouds, which, at a small distance, resemble the minutely shaded parts of an engraving, and, at the same time, traversed by innumerable small and irregular veins of black and white. It receives a fine polish, and is well fitted for ornamental works.

Some of the white marble of Vermont, and that which may be obtained at Smithfield, in Rhode Island, more peculiarly deserve the name of *statuary* marble.

*Flexible Marble* has been observed at Pittsford, Rutland county, Vermont; and at Pittsfield, in Massachusetts.

*Pennsylvania Marble.* There is found at Aaronsburg, in Northumberland county, a black marble. It is of compact limestone, containing white specks. At Marbletown, near the Hudson River, in the State of New York, is a quarry of very fine black marble, spotted with white shells. Marble has also been found in Virginia, and some other of the United States. But the state of the arts has not, hitherto, directed the attention of the curious so much to this subject as it intrinsically deserves.

### SECTION II. — The Polishing of Marble.

The art of cutting and polishing marble was, of course, known to the ancients, whose mode of proceeding appears to have been nearly the same with that employed at present; except, perhaps, that they were unacquainted with those superior mechanical means, which now greatly facilitate the labor, and diminish the expense of the articles thus produced. There are many manufactories of this kind, generally called marble-mills, on the continent, and also in Great Britain;

but as the principle on which they proceed is nearly the same in all, it will suffice in this place to give the description of one or two of the latter.

An essential part of the art of polishing marble is the choice of substances by which the prominent parts are to be removed. The first substance should be the sharpest sand, so as to cut as fast as possible, and this is to be used till the surface becomes perfectly flat. After this, the surface is rubbed with a finer sand, and frequently with a third. The next substance, after the finest sand, is emery, of different degrees of fineness. This is followed by the red powder called tripoli, which owes its cutting quality to the oxide of iron it contains. Common iron-stone, powdered and levigated, answers the purpose very well. This last substance gives a tolerably fine polish. This, however, is not deemed sufficient. The last polish is given with putty. After the first process, which merely takes away the inequalities of the surface, the sand employed in preparing it for the emery should be chosen of an uniform quality. If it abounds with some particles harder than the rest, the surface will be liable to be scratched so deep as not to be removed by the emery. In order to get the sand of uniform quality, it should be levigated and washed. The hard particles being generally of a different specific gravity to the rest, may, by this means, be separated. This method will be found much superior to that of sifting. The substance by which the sand is rubbed upon the marble is generally an iron plate, especially for the first process. A plate of an alloy of lead and tin is better for the succeeding processes, with the fine sand and emery. The rubbers used for the polishing, or last process, consist of coarse linen cloths, such as hop-bagging, wedged tight into an iron plane. In all of these processes, a constant supply of water, in small quantities, is absolutely necessary.

The sawing of marble is performed on the same principles as the first process of polishing. The saw is of soft iron, and is continually supplied with water and the sharpest sand.

Marble is extensively used for building, statuary, decorations, and inscriptions. In warm countries it is one of the most durable of substances, as is proved by the edifices of Athens, which have retained their polish for more than two thousand years. Severe frost, preceded by moisture, causes it to crack and scale; great heat reduces it to quicklime. It may be burnt, like other varieties of lime-stone, into lime for preparing mortar, or employed as a flux for certain ores, particularly those which contain alumine and silex.

White marble is sometimes cleaned by muriatic acid diluted with water. Spots of oil stain white marble, so that they cannot be taken out.

## SECTION III. — Artificial Marble.

The stucco, whereof they make statues, busts, basso-relievos, and other ornaments of architecture, ought to be marble pulverized, mixed in a certain proportion with plaster; the whole well sifted, worked up with water, and used like common plaster. (See *Stucco.*)

There is also a kind of artificial marble, made of flake selenites, or a transparent stone resembling the plaster, which becomes very hard and receives a tolerable polish, and may deceive the eye. This kind of selenites resembles Muscovy talc. There is another sort of artificial marble, formed by corrosive tincture, which, penetrating into white marble, to the depth of a line or more, imitates the various colors of other dearer marbles. There is also a preparation of brimstone in imitation of marble. To do this you must provide yourself with a flat and smooth piece of marble. On this make a border or wall, to encompass either a square or oval table, which may be done either with wax or clay. Then, having provided several sorts of colors, as white lead, vermilion, lake, orpiment, massicot, Prussian-blue, &c., melt, on a slow fire, some brimstone, in several glazed pipkins; put one particular sort of color into each, and stir it well together; then, having before oiled the marble all over within the wall, with one color quickly drop spots upon it of larger and less size; after this take another color, and do as before; and so on, till the stone is covered with spots of all the colors you design to use. When this is done, you are next to consider what color the mass or ground of your table is to be; if of a gray color, then take fine sifted ashes, and mix them up with melted brimstone, or if red, with English red ochre; if white, with white lead; if black, with lamp or ivory black. Your brimstone for the ground must be pretty hot, that the colored drops on the stone may unite and incorporate with it. When the ground is poured even all over, you are next, if judged necessary, to put a thin wainscot board upon it; this must be done while the brimstone is hot, making also the board hot, which ought to be thoroughly dry, in order to cause the brimstone to stick the better to it. When the whole is cold, take it up, and polish it with a cloth and oil, and it will look very beautiful.

## SECTION IV. — The Coloring of Marble.

The coloring of marble is a nice art, and, in order to succeed in it, the pieces of marble on which the experiments are tried must be well polished, and clear from the least spot or vein. The harder the marble is, the better it will be, and the greater the heat necessary in the operation ; therefore, alabaster, and the common soft white marble, are very improper to perform these operations upon.

Heat is always necessary, for the opening of the pores, so as to render it fit to receive the colors; but the marble must never be made red-hot, for then the texture of the marble itself is injured, and the colors are burnt, and lose their beauty. Too small a degree of heat is as bad as too great; for, in this case, though the marble receives the color, it will not be fixed in it, nor strike deep enough. Some colors will strike even cold; but they are never so well sunk in as when a just degree of heat is used. The proper degree is that, which, without making the marble red, will make the liquor boil on its surface. The menstruums used to strike in the colors must be varied according to the nature of the color to be used. A lixivium made of horse's or dog's urine, with four parts of quicklime, and one part pot-ashes, is excellent for some colors; common lye of wood-ashes does very well for others; for some, spirit of wine is best; and finally, for others, oily liquors, or common white wine.

The colors which have been found to succeed best with the peculiar menstruums, are these: stone-blue dissolved in six times the quantity of spirit of wine, or of the urinous lixivium, and that color which the painters call litmus dissolved in common lye of wood-ashes. An extract of saffron, and that color made of buckthorn berries, and called by the painters soap-green, both succeed well dissolved in urine and quicklime, and tolerably well in spirit of wine. Vermilion, and a fine powder of cochineal, succeed also very well in the same liquors. Dragon's-blood succeeds very well in spirit of wine, as does also a tincture of logwood in the same spirit. Alkanet-root gives a fine color, but the only menstruum to be used for this is oil of turpentine; for neither spirit of wine, nor any lixivium, will do with it. There is a kind of substance called dragon's-blood-in-tears, which, mixed with urine alone, gives a very elegant color.

Besides these mixtures of colors and menstruums, there are some colors which are to be laid on dry and unmixed. These are dragon's-blood of the purest kind, for a red; gamboge, for a yellow; green wax, for a green; common brimstone, pitch, and turpentine, for a brown color. The marble, for these experiments, must be made considerably hot, and the colors are to be rubbed on dry, in the lump. Some of these colors, when once given, remain immutable; others are easily changed or destroyed. Thus the red color, given by dragon's-blood, or by the decoction of logwood, will be wholly taken away by oil of tartar, and the polish of the marble not hurt by it.

A fine gold color is given in the following manner: take crude sal-ammoniac, vitriol, and verdigris, of each equal quantities; white vitriol succeeds best, and all must be thoroughly mixed in fine powder.

The staining of marble, to all degrees of red or yellow, by solution of dragon's-blood or gamboge, may be done by reducing these gums to powder, and grinding them with the spirit of wine, in a glass mortar; but for smaller attempts, no method is so good as the mixing a little of either of these powders with spirit of wine, in a silver spoon, and holding it over burning charcoal. By this means, a fine tincture will be extracted, and, with a pencil dipped in this, the finest traces may be made on the marble, while cold, which, on heating of it afterwards, either on sand or in a baker's oven, will all sink very deep, and remain perfectly distinct in the stone. It is very easy to make the ground-color of the marble red or yellow, by this means, and leave white veins in it. This is to be done by covering the places where the whiteness is to remain with some white paint, or even with two or three doubles only of paper, either of which will prevent the color from penetrating in that part. All the degrees of red are to be given to the marble by the means of this gum alone; a slight tincture of it, without the assistance of heat to the marble, gives only a pale fleshcolor; but the stronger tinctures give it yet deeper. To this the assistance of heat adds yet greatly; and finally, the addition of a little pitch to the tincture gives it a tendency to blackness, or any degree of deep red that is desired.

A blue color may be given to marble, by dissolving turnsol in a lixivium of lime and urine, or in the volatile spirit of urine; but this has always a tendency to purple, whether made by one or the other of these ways. A better blue, and used in an easier manner, is furnished by the Canary turnsol, a substance well known among the dyers. This need only be dissolved in water, and drawn on the place with a pencil; this penetrates very deep into the marble, and the color may be increased by drawing the pencil, wetted afresh, several times over the same lines. This color is subject to spread and diffuse itself irregularly; but it may be kept in regular bounds, by circumscribing its lines with beds of wax, or any other substance. It is to be observed, that this color should always be laid on cold, and no heat given ever afterwards to the marble; and one great advantage of this color is, that it is easily added to marbles already stained with any other colors, and it is a very beautiful tinge, and lasts a long time.

This art has, in several persons' hands, been a very lucrative secret, though there is scarcely any thing in it, that has not, at one time or another, been published.

Kircher has the honor of being one of the first who published any thing practicable about it. This author, meeting with stones in some cabinets, supposed to be natural, but having figures too nice and particular to be supposed to be

Nature's making, and these not only on the surface, but sunk through the whole body of the stones, was at the pains of finding out the artist who did the business; and on his refusing to part with the secret on any terms, this author, with Albert Gunter, a Saxon, endeavoured to find it out. Their method is this. Take nitric acid and nitro-muriatic acid, of each one ounce, sal-ammoniac one ounce, spirit of wine two drachms, about twenty-six grains of gold, and two drachms of pure silver; let the silver be calcined and put into a vial, and pour upon it the nitric acid; let this stand some time, then evaporate it, and the remainder will at first appear of a blue, and afterwards of a black color; then put the gold into another vial, and pour the nitro-muriatic acid upon it, and when it is dissolved, evaporate it as the former; then put the spirit of wine upon the sal-ammoniac, and let it be evaporated in the same manner. All the remainders, and many others made in the same manner from other metals, dissolved in their proper acid menstrua, are to be kept separate, and used with a pencil on the marble. These will penetrate without the least assistance of heat, and, the figure being traced with a pencil on the marble, the several parts are to be touched over with the proper colors, and this renewed daily, till the colors have penetrated to the desired depth into the stone.

After this, the mass may be cut into thin plates, and every one of them will have the figure exactly represented on both surfaces, the colors never spreading.

The nicest method of applying these, or the other tinging substances, to marble that is to be wrought into any ornamental works, and where the back is not exposed to view, is to apply the colors behind, and renew them often, till the figure is sufficiently seen through the surface on the front, though it does not quite extend to it. This is the method that, of all others, brings the stone to a nearer resemblance of natural veins of this kind. The same author gives another method to color marble, by vitriol, bitumen, &c. Forming a design of what you like upon paper, and laying the said design between two pieces of polished marble, then, closing all the interstices with wax, you bury them for a month or two in a damp place; on taking them up, you will find that the design you painted on the paper has penetrated the marbles, and formed exactly the same design upon them.

## SECTION V. — Granite.

Granite is apparently the oldest and deepest of rocks. It is one of the hardest and most durable which have been wrought, and is obtained in larger pieces than any other rock. Granite is a compound stone, varying in color and coarseness. It consists of three constituent parts, united to each other without the intervention of any cement, namely, *quartz*, the material of rock-crystal; *feldspar*, which gives it its color; and lastly *mica*, a transparent, thin, or foliated substance.

But in order to understand more perfectly the nature and qualities of granite, some examination of its constituent parts is necessary.

I. Quartz belongs to that class of minerals denominated *earthy compounds*, or *stones*. It embraces numerous varieties, differing much in their forms, texture, and other external characters. And although but few well defined external characters apply to the whole species, yet most of its varieties are easily recognized.

It is sufficiently hard to scratch glass, and it always gives sparks with steel. When pure, its specific gravity is about 2.63, water being 1; but in certain varieties extends above and below this term, depending on its structure, or the presence of foreign ingredients. Indeed the mean specific gravity of the whole species is about 2.60. It is sometimes in amorphous masses, and sometimes in very beautiful crystals, of which the primitive form is a rhomb slightly obtuse, the angles of its faces being 94° 24′ and 85° 36′. The secondary form, the most common, is a six-sided prism, terminated by six-sided pyramids. It exhibits double refraction, which must be observed by viewing an object through one face of the pyramid and the opposite side of the prism. Its fracture is vitreous.

*Chemical Characters.* All the varieties of quartz are infusible by the blow-pipe, and if pure, it is scarcely softened, even when the flame is excited by oxygen gas. Before the compound blow-pipe, a fragment of rock-crystal instantly melts into a white glass. Quartz is essentially composed of silex, or the principal ingredient of flint, from 93 to 98 parts being of this substance, and the residue alumine, lime, water, or some metallic oxide.

Among the varieties, are, — 1. The *Limpid Quartz* (Rock-crystal). This, the most perfect variety of quartz, has, when crystallized, received the name of *rock-crystal;* indeed the same name is sometimes extended to colored crystals, when transparent. Limpid quartz is without color, and sometimes as transparent as the most perfect glass, which it strongly resembles. It is, however, harder than glass, and the flaws or bubbles, which it often contains, lie in the same plane, while those in glass are irregularly scattered. The finest crystals are found in veins, or cavities, in primitive rocks, as in granite, gneiss, or mica slate, or in alluvial earths.

In the United States this variety is not uncommon. It is found in Virginia, near the North Mountain. In Frederick county, Maryland, crystals are scattered on the surface of the ground, of perfect transparency, with a splendid lustre. In New York, on an island in Lake George, are very fine crystals, — and in Vermont, at Grafton. This variety is sometimes employed in jewelry, for watch-seals, &c.

2. *Smoky Quartz.* Objects seen through this variety, seem to be viewed through a cloud of *smoke.* Its true color seems to be clove-brown. It is sometimes called *smoky topaz.*

3. *Yellow Quartz.* Its color is pale yellow, sometimes honey or straw-yellow. It has been called *citrine;* and also *false,* or *Bohemian, topaz.*

4. *Blue Quartz.* Its color is blue, or grayish-blue. It is inferior in hardness to the former varieties.

5. *Rose-red Quartz.* Its color is rose-red, of different shades, sometimes with a tinge of yellow. It is seldom more than semi-transparent. Its color, which is supposed to arise from manganese, is said to be injured by exposure to light. It has been called *Bohemian ruby.* It is sometimes employed in jewelry, and much esteemed.

6. *Irised Quartz.* It reflects a series of colors, similar to those of the iris or rainbow.

7. *Aventurine Quartz.* Its predominant color, which may be red, yellow, gray, greenish, blackish, or even white, is variegated by brilliant points, which shine with silver or golden lustre. It is sometimes employed in ornaments of jewelry.

8. *Milky Quartz.* Its color is milk-white, in some cases a little bluish; and it is nearly opaque. Its fracture has sometimes a resinous lustre. It is sometimes in small crystals, but more often in large masses.

9. *Greasy Quartz.* Its colors are various, either light or dark. Its fracture appears as if rubbed with oil.

10. *Radiated Quartz.* It is in masses which have a crystalline structure, and are composed of imperfect prisms. These prisms usually diverge a little, or radiate from the centre, and often separate with great ease.

11. *Tabular Quartz.* It occurs in plates of various sizes, which are sometimes applied to each other by the broader faces.

12. *Granular Quartz.* Its structure presents small granular concretions, or grains, which are sometimes feebly united. This variety must be carefully distinguished from certain sandstones which it resembles. It may be important in the manufacture of glass, and certain kinds of stone ware.

13. *Arenaceous Quartz.* It is in loose grains, coarse or fine, either angular or rounded, and constitutes some varieties of pure sand. Certain sandstones appear to be composed of this quartz, united by some cement.

14. *Pseudomorphous Quartz.* It appears under regular forms, such as cubes, octahedrons, &c., which do not belong to the species. They are opaque, their surfaces dull, and their edges often blunted.

Common quartz never forms whole mountains. It is sometimes in large masses, or in beds, and frequently in extremely large veins, which have been mistaken for beds. Quartz, in the form of crystallized grains, or of irregular masses of various sizes, is abundantly disseminated in granite, gneiss, mica slate, &c., of all which it forms a constituent part. It is sometimes in regular crystals, dispersed through the granite. In porphyry, also, it is sometimes regularly crystallized. It also occurs in carbonate of lime, anthracite, &c. Among secondary rocks, quartz is found, forming a greater part of many sandstones; also between strata of compact limestone, of clay, or of marl, or imbedded in sulphate of lime.

In alluvial earths it exists in the form of sand. Quartz is often associated with the carbonate and fluate of lime, sulphate of barytes, and feldspar, in metallic veins; indeed, it exists in almost every metallic vein.

Hornblende, schorl, epidote, garnet, magnetic iron, are also among the minerals contained in quartz. Mica gives it a slaty structure.

In some rare instances, bubbles of air, and even drops of water, and bitumen, have been found in quartz. Although common quartz never contains any organic remains, it is sometimes crystallized in fossil wood.

Quartz is found very abundantly in most of the Northern and Middle States.

We have already seen that certain varieties of quartz are employed in jewelry. It is also used, especially the sandy variety, in the manufacture of glass; also in the preparation of smalt and certain enamels.

II. Feldspar. This important and widely distributed mineral has, in most of its varieties, a structure very distinctly foliated. It scratches glass, and gives sparks with steel, but its hardness is a little inferior to that of quartz. When in crystals or crystalline masses, it is very susceptible of mechanical division, at natural joints, which, in two directions perpendicular to each other, are extremely perfect; but in the third direction they are usually indistinct.

The primitive form, thus obtained, is an oblique-angled parallelogram, whose sides are inclined to each other in angles of 90°, 120°, and 111° 28′. The four sides, produced by the two divisions perpendicular to each other, have a brilliant polish, while the two other sides are dull; this is a distinctive character of great importance. Its specific gravity usually lies between 2.43 and 2.70. It possesses double refraction, which, however, is not easily observed. It is usually phosphorescent, by friction, in the dark.

*Chemical Characters.* Before the blow-pipe it melts into a white enamel, or glass, more or less translucent. The results of analysis have not yet been perfectly satisfactory in regard to the true composition of feldspar. It appears probable, however, that not only silex and alumine, but also lime and potash, are essential ingredients. In a specimen of green feldspar, Vauquebin found 62.83

parts of silex, 17.02 of alumine, 13.0 of potash, 3.0 of lime, and 1.0 of oxide of iron, = 96.85 in a hundred parts.

Several of the varieties of feldspar deserve notice.

1. *Common Feldspar.* This variety occurs in fragments often rolled, also in grains in sand, but more commonly in masses of moderate size, forming an ingredient of compound minerals. It is not unfrequently in regular crystals of the primitive form, already mentioned.

The crystals of feldspar, seldom very small, are sometimes *several inches* both in diameter and length; their faces are shining, and their edges sometimes very perfect. Their prevailing form is an oblique prism, whose sides are unequal, and vary in number, from four to ten. The terminating faces, of which two are commonly longer than the others, are subject to great variation in number and extent; indeed, they often seem to have no symmetry in their arrangement, a circumstance which arises from the obliquity and irregularity of the primitive form.

The longitudinal fracture is foliated, and its lustre more or less shining and vitreous, sometimes pearly, especially in certain spots; the cross fracture is uneven or splintery, and nearly dull. It is easily broken, and falls into rhomboidal fragments, which have four polished faces. The folia are sometimes curved, or arranged like the petals of a flower.

It is more or less translucent, sometimes nearly or quite opaque, and presents a great variety of colors. Among these are white, tinged with gray, yellow, green, or red; gray, often with a shade of blue; several shades of red, as flesh or blood-red; to which must be added green, yellow, brown, or even black.

This variety is abundant, and constitutes an essential ingredient of granite, gneiss, sienite, and greenstone. Of granite and sienite it sometimes forms two thirds of the whole mass. It exists also in argillite and porphyry, &c. Its crystals, though sometimes imbedded, are more often found in the fissures or cavities of these rocks, and are sometimes associated with epidote, axinite, chronite, amianthus, carbonate of lime, quartz, magnetic oxide of iron, &c.

2. *Green Feldspar.* The variety is rare, and has an apple-green color, varying somewhat in intensity, and sometimes marked with whitish stripes.

3. *Adularia.* This is the most perfect variety of feldspar, and bears to common feldspar, in many respects, the relation of rock-crystal to common quartz. It is more or less translucent, and sometimes transparent and limpid. Its color is white, either a little milky, or with a tinge of green, yellow, or red. But it is chiefly distinguished by presenting, when in certain positions, whitish reflections, which are often slightly tinged with blue or green, and exhibit a pearly or silver lustre. Adularia is sometimes cut into plates and polished. The *fish's eye moon-*

*stone* and *argentine* of lapidaries come chiefly from Persia, Arabia, and Ceylon, and belong to adularia, as do also the *water-opal* and *girasole* of the Italians.

4. *Opalescent Feldspar.* This very beautiful variety is distinguished by its property of reflecting light of different colors, which appear to proceed from its interior. Its proper color is gray, often dark or blackish-gray, and sometimes specimens are marked with whitish spots or veins. But when held in certain positions it reflects a very lively and beautiful play of colors, embracing almost every shade of green and blue, and several shades of yellow, red, gray, and brown. These colors are usually confined to certain spots, and even the same spot changes its color in different positions. It is much esteemed in jewelry.

5. *Aventurine Feldspar.* Its colors are various; but it contains little spangles or points, which reflect a brilliant light.

6. *Petuntze.* It is nearly or quite opaque, and its color is usually whitish or gray. It has, in most cases, less lustre than common feldspar. It most usually occurs in beds. Its powder is said to have a slightly saline taste. It is used in the manufacture of porcelain, both for an enamel and its composition.

7. *Granular Feldspar.* It is nearly or quite opaque, and imperfectly foliated. It varies much in hardness, and is sometimes friable between the fingers. Its color is usually white, and sometimes strongly resembles masses of white sugar. Feldspar is found in the Northern, and most of the Middle States.

III. Mica. Mica appears to be always the result of crystallization, but it is rarely found in regular, well-defined crystals. Most commonly it appears in thin, flexible, elastic laminæ, which exhibit a high polish and strong lustre. These laminæ have sometimes an extent of many square inches; and from this gradually diminish, till they become mere spangles. They are usually found united into small masses, extremely variable in thickness, or into crystals more or less regular; their union, however, is so very feeble, that they are easily separable, and may be reduced to a surprising degree of tenuity. In this state their surface becomes irised, and their thickness does not exceed a millionth part of an inch.

The crystals of mica are sometimes right prisms with rhombic bases, whose angles are 120° and 62°. This is also the primitive form, in which one side of the base is to the height of the prism nearly as 3 to 8.

The structure of mica is always foliated, but the foliæ may be straight, curved, or undulated. The surface has a shining or splendent lustre, which is usually metallic, sometimes like that of silver or gold; and sometimes like that of polished glass. It is easily scratched by a knife, and, in most cases, even by the finger-nail. Its surface is smooth to the touch, and *very seldom* slightly unctuous; its powder is dull, grayish, and feels soft. It is often transparent; in other cases it is only translucent, sometimes at the edges only. Its colors are silver-white, gray, often tinged with yellow, green, or black; also, brown, reddish, and green. Its specific gravity extends from 2.53 to 2.93; and when rubbed on sealing-wax, it communicates to the wax negative electricity.

*Chemical Characters.* It is fusible by the blow-pipe, though sometimes with difficulty, into enamel, which is usually gray or black. The colored varieties are the most easily fusible; and black mica gives a black enamel, which often moves the needle. It contains, according to Klaproth, silex 48.0, alumine 34.25, potash 8.75, oxyd of iron 4.5, oxyd of manganese 0.5, = 96. Sometimes the potash is in greater proportion, and in black mica the oxyd of iron is sometimes as high as 22 per cent. Mica is subject to decomposition by exposure to the atmosphere.

The following are the most important varieties of mica: —

1. *Laminated Mica.* It occurs in large plates, which often contain many square inches. It has been called *Muscovy glass*, or *talc*, being found abundantly in that country.

2. *Lamellar Mica.* This is the more common variety. It exists in small foliæ, either collected into masses, or disseminated in other minerals. It is sometimes in extremely minute scales, which, when detached from the mass, appear like sand.

3. *Prismatic Mica.* This variety is not common. The laminæ are easily divisible, parallel to their edges, into minute prisms, or even into delicate filaments. The edges of the laminæ have usually more lustre than those of the other varieties.

Although mica never occurs in beds, or large insulated masses, there is no substance more universally diffused through the mineral kingdom. It is an essential ingredient in granite, gneiss, and mica-slate; and occurs also in sienite, porphyry, and other primitive rocks. Mica occurs also in greenstone, basalt, sandstone, and other secondary rocks, especially in sandstone and shell, which accompany coal.

In the United States mica is very abundant.

It has been employed, instead of glass, in the windows of dwelling-houses; also in ships of war, because it is not liable to be broken by the concussion produced by the discharge of cannon. In lanterns it is superior to horn, being more transparent, and not so easily injured by heat. When in thin, transparent laminæ, sufficiently large, it is useful to defend the eyes of those who travel, against high winds and severe storms of snow. When of suitable color and in minute scales, it is employed to ornament paper, which is then said to be *frosted;* the scales of mica are made to adhere by a solution of gum or glue.

These are the ingredients of which granite is composed.

The structure of granite is granular; but the grains are extremely variable, both in size and form. Most frequently the size of the grains lies between that of a pin's head and a nut. Sometimes, however, they are several inches, and even more than a foot, in their dimensions, and sometimes they are so minute, that the mass resembles a sandstone, or even appears almost homogeneous to the naked eye.

The forms of these grains are, in general, altogether irregular, like those of the fragments of most minerals. In some granites the feldspar or quartz, or even the mica, is in crystals more or less regular.

The ingredients of granite vary much in their proportions; but, in general, the feldspar is most abundant, and the mica is usually in the smallest proportion. Their arrangement is also various: sometimes, while the feldspar and quartz are mingled with considerable uniformity, the mica appears only in scattered masses, or is found investing grains of feldspar and quartz on all sides; in other cases the feldspar and mica, or quartz and mica, are mingled, while the third ingredient appears in small, distinct masses.

One of the ingredients of this rock, most frequently the quartz or mica, may be entirely wanting, through a greater or less portion of the mass, so that specimens of true granite (as it is sometimes called) contain only two ingredients.

The predominant color of granite usually depends on that of the feldspar, which may be white or gray, sometimes with a shade of red, yellow, blue, or green, and sometimes it is flesh-red. The quartz may be white, grayish-white, or gray, sometimes very dark; but it is usually vitreous and translucent. The mica may be black, brown, gray, silver-white, yellowish, or violet.

The simple minerals which enter into the composition of granite are, in general, so intimately united, that the mass is firm and solid; but some varieties are brittle, and easily become disintegrated. The feldspar sometimes undergoes a partial decomposition, losing its lustre, hardness, and foliated structure, while, at other times, it is converted into porcelain clay. The mica, also, when exposed to the open air, is subject to alteration, or even decomposition. Sulphuric acid is often generated by the decomposition of the sulphuret of iron, disseminated in the granite, and this acid acts upon the mica in its vicinity, thus producing a soft substance, and diminishing the firmness of the granite. Granite which embraces shorl is also liable to disintegration.

The specific gravity of granite generally lies between 2.5 and 2.6, but is sometimes higher.

Among the varieties of granite are, —

1. *Graphic Granite.* This very beautiful variety of granite is composed chiefly of feldspar and quartz. The feldspar is very abundant, forming a base,

in which quartz, under various forms, lies imbedded. When this granite is broken in a direction perpendicular to that in which the quartz traverses the feldspar, the surface of the fracture ordinarily presents the general aspect of *letters*, arranged in parallel lines; and hence its name. These letters of gray, vitreous quartz, on a shining and polished tablet of white or flesh-colored feldspar, appear extremely beautiful. It is principally this variety of granite which, by its decomposition, furnishes porcelain clay.

2. *Globular Granite.* This is composed of large, globular, distinct concretions, which are sometimes several feet in diameter. These concretions are united by a kind of granite, which is readily disintegrated, thus leaving the globular masses detached from each other.

3. *Porphyritic Granite.* This variety is produced, when large crystals of feldspar are interspersed in a fine-grained granite.

Granite is always a primitive rock; and never embraces any organic remains of animals or vegetables.

It exists very extensively, and in many countries it occurs in immense quantities. It constitutes a large portion of many of the highest mountains, of which it appears to form the central parts, as well as the summits. It is more or less abundant in the mountains of Scotland and Germany; the Alps, the Carpathian, the Uralian, and the Altaian mountains; the Andes, and the United States.

Granite is chiefly used as a building stone. It is split from the quarries by rows of iron wedges, driven simultaneously in the direction of the intended fissure. This method is thought by Brard to have been known to the ancient Romans and Egyptians. The blocks are afterwards hewn to a plane surface, by the strokes of a sharp-edged hammer. Granite is also chiselled into capitals and decorative objects, but this operation is difficult, owing to its hardness and brittleness. It is polished, by long-continued friction, with sand and emery.

The largest mass of granite known to have been transported, in modern times, is the pedestal of the equestrian statue of Peter the Great, at St. Petersburg. It is computed to weigh three million pounds, and was transported nine leagues, by rolling it on cannon-balls; those of iron being crushed, others of bronze were substituted. Sixty granite columns, at St. Petersburg, consist each of a single stone, twenty feet high. The columns in the portico of the Pantheon, at Rome, which are thirty-six feet eight inches high, are also of granite. The shaft of Pompey's Pillar, in Egypt, is sixty-three feet in height, and of a single piece. It is said to be of red granite, but is possibly sienite. In the eastern part of the United States, a beautiful white granite is found in various places, and is now introduced into building. The Quincy Market-house in Boston, the United States Bank, the Tremont House, the Tremont Temple, &c., are made of it.

## SECTION VI. — Sienite.

This rock is related to granite, and resembles it in its general characters. *Feldspar* and *hornblend* may be considered its constant and essential ingredients. Feldspar is the most abundant ingredient, and has already been described (see *Granite*); but as it is, however, the presence of hornblend as a constituent part which distinguishes this rock from granite, some account of it may be useful.

I. Hornblend is a very common mineral, and may, in general, be easily recognized. Sometimes it is in regular and distinct crystals, but more commonly it appears in masses, composed of laminæ, or fibres, variously aggregated, the result of confused crystallization.

When its structure is sufficiently regular, mechanical division is easily effected in a longitudinal direction; and its crystals are found to be composed of laminæ, situated parallel to the sides of an oblique four-sided prism, with rhombic bases; the sides of this prism are inclined to each other, at angles of 124° 34′ and 55° 26′. The longitudinal fracture is of course foliated, and usually presents the broken edges of many laminæ extending one beyond another.

Hornblend usually scratches glass, and sometimes with difficulty gives sparks with steel. Its powder is dry, and not soft to the touch. It is often opaque, sometimes translucent. It is generally black and green, often intermixed. Its specific gravity is about 3.20.

*Chemical Characters.* Before the blow-pipe it melts with considerable ease, and forms black or grayish-black glass, or grayish enamel. It yields, by analysis, silex, alumine, magnesia, and lime, but in variable proportions. Its colors are produced by the oxyds of iron and of chrome.

Masses of hornblend, whether fibrous, lamellar, or nearly compact, possess a remarkable tenacity, which renders them tough and difficult to break; indeed, a considerable cavity may often be produced by the hammer, before the mass breaks. They exhale, when moistened by the breath, a peculiar argillaceous odor.

Some of the varieties are, —

1. *Basaltic Hornblend*, which is found in lava and volcanic scoriæ, and very often in *basalt;* and hence its name. It is almost always in distinct crystals, whose color is a pure black, sometimes slightly tinged with green, or brownish, by decomposition. Their surface is sometimes strongly shining, at other times

dull, and invested with a ferruginous crust. Its structure is more foliated than that of other varieties, and its crystals more brittle.

2. *Lamellar Hornblend.* Its masses are sometimes composed merely of lamellar, and sometimes of granular, concretions of various sizes, having a lamellated structure. Hence the fracture is foliated, but the foliæ are variously inclined and interlaced.

3. *Fibrous Hornblend.* It occurs in masses, composed of acicular crystals or fibres, either broad or narrow, parallel or interlaced.

4. *Slaty Hornblend*, or *Hornblend Slate.* This variety scarcely differs from the preceding, except in the slaty structure of its masses. For each individual layer is composed of very minute fibres, diverging in bundles, or promiscuously, and often interlaced.

Hornblend is an essential ingredient in sienite and greenstone, as well as in basalt and lava.

Sienite, being composed of these two ingredients, is usually granular; but the grains are sometimes coarse, and sometimes very fine. In some instances its structure is slaty. When this rock is very fine grained, and, at the same time, contains large crystals of feldspar, it constitutes *sienitic porphyry.*

The feldspar, whose foliated texture is often very distinct, is most frequently reddish or whitish; but sometimes it receives a greenish tinge from the hornblend, or from epidote.

Sienite is sometimes found resting on granite, gneiss, mica-slate, or argillite, and sometimes it is associated with greenstone and argillaceous porphyries.

This rock is often altered at the surface by the action of the weather, more especially in those varieties which contain an uncommon proportion of feldspar. It often is susceptible of a good polish; and may be employed for the same purposes as porphyry. Its name is derived from that of Sienna, a city in Egypt, where it is found in abundance, and constitutes the material of many of the obelisks. The Romans imported it for purposes of statuary and architecture.

Sienite is obtained in large pieces, and possesses all the valuable qualities of granite as a building stone. It is somewhat harder than granite, and more difficult to chisel. It is found abundantly near Boston, at Weymouth, Brighton, Quincy, &c., and is introduced into many structures. The Washington Bank and the Bunker Hill Monument consist of this stone. It is rendered, by its extreme hardness, one of the best materials for macadamizing roads. The railway at Quincy is built for transporting this stone from the quarry to the sea, and it is there commonly called the *Quincy stone.*

## SECTION VII. — Greenstone.

Sienite and greenstone are essentially composed of the same ingredients, namely, *feldspar* and *hornblend.* And the two rocks do, in fact, pass into each other by insensible shades. But in greenstone the hornblend predominates, while in sienite the feldspar is the most abundant ingredient. This frequently gives to this stone more or less of a greenish tinge, especially when it is moistened; hence the name of this rock. Sometimes the tinge of green is considerable lively; sometimes, also, its color is a dark gray, or grayish-black. In short, its color, especially at the surface, is often modified by the presence of oxyd of iron.

It presents a considerable diversity of aspect, depending on the general structure, or on the size, proportion, disposition, and more or less intimate mixture of its constituent parts. From greenstone, with a coarse granular structure, to those varieties whose texture is so finely granular that the two ingredients can scarcely be perceived, there is a gradual passage, exhibiting every intermediate step. Indeed, the grains are sometimes so minute, and so uniformly and intimately mingled, that the mass appears altogether homogeneous, and the different ingredients are hardly perceptible, even with a glass.

It sometimes presents prisms or columns of various size. These prisms may have from three to seven sides, and are often quite regular. Many greenstones are susceptible of a polish. It occurs in beds, more or less large, and sometimes forms whole mountains.

Greenstone is common in the United States. When this rock breaks into prismatic fragments, it forms a very useful building stone. Most of its varieties, when heated red-hot, plunged into cold water, and pulverized, become a good substitute for puzzolana in preparing water-proof mortar for the construction of walls, cellars, docks, piers, &c. This rock has sometimes received the appellation of *trap*, which seems to be a generic term, applied to those stones which consist principally of *hornblend.*

## SECTION VIII. — Sandstone, or Freestone.

Sandstone is composed, generally, of grains of quartz (see *Granite*), united by a cement, which is never very abundant, and often, indeed, nearly or quite invisible. These grains are sometimes scarcely distinguishable by the naked eye, and sometimes their magnitude is equal to that of a nut or an egg.

The cement is variable in quantity, and may be calcareous or merely argillaceous or siliceous. When siliceous, the mineral much resembles quartz. The texture of some sandstones is very close, while that of others is so loose and porous as to permit the passage of water.

Some varieties are sufficiently hard to give fire with steel, while others are friable, and may be reduced to powder even by the fingers; this is often the case with those sandstones whose cement is marly.

Its fracture is always granular or earthy; in some instances it may, at the same time, be splintery. Some sandstones have a slaty structure, arising from scattered plates of mica, and have been called *sandstone slate.*

Its most common color is gray or grayish; it is sometimes reddish, or reddish-brown. In some cases the color is uniform, in others variegated.

Among the varieties are, —

1. *Red Sandstone.* The grains of this variety are usually coarse, and united by an argillaceous cement, which is at the same time ferruginous; hence the dark reddish or reddish-brown color which it presents.

2. *Variegated Sandstone.* This presents a variety of colors; as yellow, green, brown, red, and white, which are usually arranged in stripes, or zones, either straight or wavering. It has commonly a close texture and fine grain; but it very often embraces roundish masses of clay, which often fall out when exposed to the weather, and diminish its value for the purposes of architecture.

3. *White Sandstone.* This includes many of the more common and valuable varieties of sandstone. Its color is whitish-gray or gray, and generally uniform; but sometimes it is marked with reddish spots. Its cement is often calcareous. It is well adapted for various uses in the arts.

Sandstone is, in general, more or less distinctly stratified. Its beds are very often nearly or quite horizontal; but sometimes, especially in the older varieties, they are much inclined, or even vertical. Sometimes, also, when in the vicinity of primitive mountains, its beds are thin, and much bent or waved. Beds of sandstone are sometimes intersected with fissures perpendicular to the direction of the strata, and hence fall into tabular masses, which are often very large.

Sandstone is found in various parts of the United States, and is, in some of its varieties, very useful in the arts. It is frequently known by the name of *freestone.* When sufficiently solid, it is employed as a building stone. In most cases, it is of moderate hardness, and cuts equally well in all directions. Some varieties naturally divide into prismatic masses. It is sometimes used as millstones, for grinding meal, or for wearing down other minerals, preparatory to a polish. These stones, when rapidly revolving, have been known to burst with a loud and dangerous explosion. When the texture is sufficiently loose and porous, it is employed for filtering water. Some varieties are used for whetstones.

Sandstone is used for buildings, in various parts of Europe. In Africa, the Temple of Hermopolis is composed of enormous masses of this stone. In America, the Capitol at Washington is of the Potomac freestone or sandstone; likewise the façade of St. Paul's Church, in Boston.

## SECTION IX. — Gneiss.

This rock, like granite, is composed of *feldspar*, *quartz*, and *mica*. But there is in gneiss less feldspar and more mica, than in granite ; but even in this substance the feldspar appears in many cases to be the predominant ingredient. Its structure is always more or less distinctly slaty, when viewed in the mass ; although individual layers, composed chiefly of feldspar and quartz, may possess a granular structure. The layers, whether straight or curved, are frequently thick; but often vary considerably in the same specimen; and when the mineral is broken perpendicular to the direction of the strata, its fracture has commonly a striped aspect. It splits easily in the direction of the strata, especially when a separation is made in a layer of mica. When gneiss is broken in the direction of the strata, the mica often seems more abundant than the other ingredients, but when seen on the cross fracture, it obviously exists in less proportion than the feldspar or quartz.

The plates, or foliæ, of mica, are usually arranged parallel to the direction of the strata, and in some varieties are chiefly collected into thin parallel layers, separated by those of feldspar and quartz. The grains of feldspar are often flattened in the direction of the strata.

The feldspar is usually white, or gray, sometimes with a tinge of yellow or red. The quartz is ordinarily grayish-white ; and the mica is often black, but sometimes gray.

The hardness of gneiss is variable ; and the feldspar and mica are subject to the same changes as when they exist in granite.

Gneiss, like granite, never embraces any petrifactions, and is always a primitive rock.

When gneiss occurs with granite, it usually lies immediately over the granite ; or, if the strata be highly inclined, it appears rather to rest against the granite, than to be incumbent upon it.

This rock, as has been intimated, assumes sometimes a granular structure, and passes, by imperceptible shades, into granite.

4

Mountains composed of gneiss are seldom so steep as those of granite.

This rock is abundant in the United States. It is useful for many purposes, in consequence of the facility with which it splits into masses of regular form.

## SECTION X. — Mica-slate.

Mica-slate is essentially composed of *mica* and *quartz* (see *Granite*), which are, in general, more or less intimately mingled; but sometimes the two ingredients alternate in distinct layers. Although the proportions of mica-slate are variable, the mica usually predominates.

The quartz is most frequently grayish-white; but the mica may be whitish, or gray, bluish-gray, or greenish, brownish, deep blue, or nearly black.

Its structure is always distinctly slaty, more so than that of gneiss; and its masses are often very fissile. The layers are sometimes straight and sometimes undulated. In some varieties the texture is very fine, and the foliæ of mica so small that they are scarcely discernible by the eye, unless their aggregation be previously destroyed by heat.

This rock has often a very high lustre, when viewed by the reflected rays of the sun. It is, however, subject to decomposition, by which its aspect is much altered.

Mica-slate is a primitive rock; but seldom appears in high, steep cliffs like those of granite. When it forms hills, the summits are usually much rounded. It abounds in ores, which exist both in beds and veins; but more frequently in beds. It is less abundant in the United States than gneiss. It is sometimes split into tabular masses, and employed for many common purposes. It is extremely useful in constructing the hearths and sides of furnaces for smelting iron.

## SECTION XI. — Slate.

Slate is an argillaceous stone, characterized by easily splitting into large, thin, and straight layers, or plates, which are sonorous when struck by a hard body. It is dull, or has only a feeble lustre. Its colors are blackish-gray, or bluish-black, bluish, or reddish-brown, or greenish, &c.

It belongs both to secondary and primary rocks. Its structure, *en masse*, is tabular; the small structure lamellar; the cleavage of the laminæ being parallel with the tables.

Slate rocks vary in hardness, but they yield to the knife. They consist of an intimate intermixture, in various proportions, of siliceous earth, alumine, and iron; and sometimes contain a portion of lime, magnesia, manganese, and bitumen. Slate forms entire mountains, and sometimes distinct beds, alternating with other rocks. It most frequently rests on granite, gneiss, and mica-slate.

As this substance forms the most light, elegant, and durable covering for houses, and is, of course, of considerable value, it is rather surprising that so much indifference prevails respecting the search for it, in those districts where common slate, or *clay-slate*, abounds. We believe all the roof-slate quarries at present worked are those which accident has discovered. This neglect is the more remarkable, when we consider the great expense frequently incurred for coal, a substance of less value in proportion to the weight.

All the best beds of roof-slate, it is believed, improve as they sink deeper into the earth; and few, if any, are of a good quality near the surface, or are indeed suitable for the purpose of roofing. There cannot be a doubt, that many beds of slate, which appear shattered and unfit for architectural use, would be found of good quality a few yards under the surface; for the best slate, in many quarries, loses its property of splitting into thin laminæ by exposure to the air.

Though the specific gravity of slate from different quarries is the same, yet all the sorts are not capable of being split into an equal degree of thickness. It is good slate which will split into laminæ of one eighth of an inch in thickness. It then weighs rather more than twenty-six ounces to a square foot, when applied to the covering of a roof. In some instances, slate of a thinner quality is used, where cheapness rather than durability is the principal object of the architect. According to an estimate of Dr Watson, the relative weights of a covering of the following different materials, for forty-two square yards of roof, are, —

| | | |
|---|---|---|
| Copper, - - | 4 | Cwt. |
| Fine Slate, - | 26 | " |
| Lead, - - | 27 | " |
| Coarse Slate, - | 36 | " |
| Tile, - - | 54 | " |

Slate, to be of a good quality for building, besides possessing the property of splitting into thin laminæ, should resist the absorption of water; to prove which, it should be kept some time immersed in water, being weighed before and after the immersion, wiping the surface dry; it is obvious that the slate which gains the least weight by this process is the least absorbent. It should resist the process of natural decomposition by air and moisture; this depends on its chemical composition and compactness, and is shown by its resisting the process of vegetation. That slate which is most liable to decay, will be the soonest covered with lichens, mosses, &c. The hardness of slate principally arises from the silex it contains, which is of all earths the least favorable to vegetation. Those slates which are the hardest when first taken from the quarry, and which have the least specific gravity, are to be preferred; for the increase in weight is owing to the presence of iron, to which slate and other stones, in some measure, owe their decomposition; while alumine renders them soft and absorbent.

Slate is so durable, in some cases, as to have been known to continue sound and good for centuries. However, unless it should be brought from a quarry of well reputed goodness, it is necessary to try its properties, which may be done by striking the slate sharply against a large stone, and if it produce a complete sound it is a mark of goodness; but if, in hewing, it does not shatter before the edge of the instrument commonly used for that purpose, the criterion is decisive. The goodness of slate may be farther estimated by its color; the deep blue-black kind is apt to imbibe moisture, but the lighter blue is always impenetrable. The touch, also, in some degree, may be a good guide, for a good firm stone feels somewhat hard and rough, whereas an open slate feels very smooth, and, as it were, greasy. Another method of trying the goodness of slate is, to place the slatestone lengthwise and perpendicularly in a tub of water, about half a foot deep, care being taken that the upper or unimmersed part of the slate be not accidentally wetted by the hand, or otherwise; let it remain in this state twenty-four hours; and, if good and firm stone, it will not draw water more than half an inch above the surface of the water, and that, perhaps, at the edges only, those parts having been a little loosened in hewing; but a spongy, defective stone will draw water to the very top.

Roof-slate is found in Pennsylvania, on the banks of the Delaware, about seventy-five miles from Philadelphia, of a good quality. In New York, at New Paltz, Ulster county; and at Rhinebeck, Duchess county. In Dummerston, Vermont, it exists in strata nearly vertical; it is also found at Rockingham and Castleton, where it is of a pale red. It exists in Maine, at Waterville and Winslow, on the Kennebec River.

Extensive quarries of slate, of a good quality, are worked near Bangor, England; this slate is exported in large quantities to various parts of the world.

It may be noticed, that, in laying of this material, a bushel and a half of lime, and three bushels of fresh-water sand, will be sufficient for a square of work; but if it be pin-plastered, it will take about as much more; but good slate, well laid and plastered to the pin, will lie a hundred years, and on good timber a much longer time. It has been common to lay the slates dry, or on moss only, but they are much better when laid with plaster.

## SECTION XII. — Soapstone, or Steatite.

All the varieties of soapstone are so soft, that they may be cut by a knife, and, in most cases, scratched by the finger-nail. Its powder and surface are soft, and more or less unctuous to the touch. It is seldom translucent, except at the edges. Its fracture is in general splintery, earthy, or slaty, with little or no lustre.

By exposure to the heat it becomes harder, but is almost infusible by the blow-pipe. It appears to be essentially composed of silex, magnesia, and perhaps alumine.

The common variety is usually solid, with a compact texture; its surface is often like soap to the touch; but sometimes it is found of a considerable degree of hardness.

Its color is usually gray or white, seldom pure, but occasionally mixed with yellow, green, or red, and is sometimes a pale yellow, reddish, or green of different shades. The colors sometimes appear in spots, veins, &c.

Its specific gravity usually lies between 2.58 and 2.79. When solid it is somewhat difficult to break. Before the blow-pipe it whitens and becomes hard, and is with difficulty reduced into a whitish paste or enamel, often, however, only at the extremity of the fragment. Some specimens have yielded by analyzation, silex 64 parts, magnesia 22, alumine 3, water 5, iron and manganese 5.

Soapstone occurs in masses, or veins, or small beds, in primitive and transition rocks, more particularly in serpentine. It is sometimes mixed with talc, mica, quartz, and asbestos; or is found incrusted with other minerals.

This stone is not uncommon. It is found in various parts of the United States. Among the best quarries for fire-proof stone is that of Francestown, New Hampshire. It occurs, also, in Connecticut, near New Haven, and at Oxford, Grafton, and Athens, in Vermont.

Soapstone, on account of its softness, is wrought with the same tools as wood. It receives a tolerable polish, and is sometimes used in building, but is not always durable. It is, however, of great importance in the construction of fire-places and stoves, and is extensively used for this purpose. Slabs of good soapstone, when not exposed to mechanical injury, frequently last eight or ten years, under the influence of a common fire on one side, and of cold air on the other. It grows harder in the fire, but does not readily crack, nor change its dimensions sufficiently to affect its usefulness. Owing to the facility with which it is wrought, its joints may be made sufficiently tight without dependence on cement.

It is often wrought into various utensils by turning, and is advantageously employed for aqueducts. It has been found to be one of the best materials for counteracting friction in machinery, for which purpose it is used in powder, mixed with oil. It has also been employed for the purpose of engraving. By being easily cut, when soft, it may be made to assume any desired form, and afterwards rendered hard by heat; it then becomes susceptible of a polish, and may be variously colored by metallic solutions.

## SECTION XIII. — Gypsum.

Gypsum is a term applied in its restricted sense to those varieties of sulphate of lime which have a *fibrous* or *granular* structure, being the result of confused crystallization, and to those, whose texture is *compact,* or earthy. It is a substance that is interesting on account of its uses in agriculture and the arts. Its colors are commonly white or gray, sometimes shaded with yellow, red, or variously mingled.

It occurs in compact masses, sometimes granular, and sometimes in parallel fibres. Though sometimes coarse, the fibres are often fine and delicate, glistening with a pearly satin lustre. Its fracture is foliated, sometimes splintery; it is generally translucent, often in amorphous masses; but not unfrequently crystallized. It is less hard than carbonate of lime. Its specific gravity usually lies between 2.26 and 2.31. By the blow-pipe it may be melted, though not very easily, into a white enamel, which shortly falls into a powder. It does not effervesce with acids, if it be pure sulphate of lime. It is soluble in about five hundred times its weight of water. It does not burn to lime.

It is composed of 32 parts of lime, 46 of sulphuric acid, and 22 parts of water; but it is often contaminated with small quantities of carbonate of lime, alumine, silex, and oxyd of iron. Some varieties are employed in sculpture and architecture under the name of alabaster; the same name is also given to some varieties of carbonate of lime.

The plaster-stone, or plaster of Paris, often contains foreign ingredients, which, in many instances, improve it as a cement.

This substance is found in abundance in many places, and has been extensively used for manure in dressing land, and appears to be useful in both clayey and sandy soils. It is also employed in the imitative and ornamental arts. Alabaster, both of the sulphate and carbonate kinds, has been used for the same purposes as marble in architecture and statuary; and, being less hard, it is more easily wrought; but is less durable and less valuable than marble. Gypsum, when deprived of its water of crystallization by burning or drying, constitutes *plaster*, and this plaster, when mixed with a certain quantity of quicklime, forms a good cement. The plaster of Paris often contains, in its natural state, a sufficient quantity of carbonate of lime to constitute a good cement after calcination.

The finer kinds of plaster, being reduced to powder, and mixed with water, have the property of becoming hard in a few minutes, and of receiving accurately the impressions of the most delicate models. It is extensively employed in stucco work, and in plastering rooms. It furnishes a delicate, white, and smooth material for architectural models, impressions of seals, &c.; and in the art of stereotyping it is indispensable. In stucco, various colors, previously ground in water, may be introduced. All these works, when dry, are susceptible of a polish.

The Temple of Fortune, called Seja, appears to have been built with some variety of sulphate of lime. It had no windows, but transmitted a mild light through its walls.

### SECTION XIV. — Puzzolana.

This substance is of volcanic origin. It usually occurs in small fragments, or friable masses, which have a dull, earthy aspect and fracture, and seems to have been baked. Its solidity does not exceed that of chalk. It is seldom tumefied, and its pores are neither large or numerous. Its colors are gray or whitish, reddish or nearly black.

By exposure to the heat it melts into a black slag. A variety examined by Bergaman yielded 55 to 60 parts of silex, 19 to 20 of alumine, 15 to 20 of iron, and 5 to 6 parts of lime. It often contains distinct particles of pumice, quartz, and scoria.

This substance is extremely useful in the preparation of a mortar which hardens quickly, even under water. When thus employed it is mixed with a small proportion of lime, perhaps one third. It has been supposed that the rapid induration of this mortar arises from the very low oxydation of the iron. If the mortar be a long time exposed to the air, previous to its use, it will not harden. The best puzzolana is said to occur in old currents of lava; but when too earthy it loses its peculiar properties. That which comes from Naples is generally gray.

## SECTION XV. — Tras, or Terras.

The nature of this is similar to some varieties of puzzolana; and it contains nearly the same principles, but with a greater proportion of lime. Its hardness is, however, much greater than that of puzzolana. Its color is brownish or yellowish; and its fracture earthy and dull. It has been found chiefly near Andernach, in the vicinity of the Rhine.

It is said to be decomposed basalt. It forms a durable water-cement when combined with lime. It is the material which has been principally employed by the Dutch, whose aquatic structures probably exceed those of any other nation in Europe. Terras mortar, though very durable in water, is inferior to the more common kinds, when exposed to the open air.

## SECTION XVI. — Quarrying.

The common methods of working and managing different sorts of quarries are in general pretty well understood by such quarrymen as are constantly employed in the business. The materials are indicated by the appearance of the surface of the earth, the nature of the substances in the vicinity, or by digging down and opening the ground by spades and other tools, or by boring with an auger made for the purpose.

The great value to mankind of such materials as coal, iron ores, &c., as well as of building materials, should induce proprietors of land to cause a more diligent and scientific search for these hidden treasures than has been hitherto practised in this country. It may also be suggested, that it would be highly beneficial and advantageous, if mineralogists and those who have an acquaintance with such substances were to turn their attention towards the appearances and accompaniments which point out such useful concealed matters; as it might greatly facilitate the search for them, and frequently lead fortuitously to their discovery. In searching for most sorts of mineral substances, coals, and some other matters, the use of the *borer* is almost constantly resorted to; but with regard to limestone, freestone, granite, &c., digging down into the earth is the mode commonly employed in the first instance, in consequence of such substances being obviously present in sufficient quantities to be wrought with advantage.

When it has been ascertained that the material exists in sufficient quantity to warrant the working of the quarry, much time and expense will be saved by proceeding in a correct manner in the first opening of it.

Instead of beginning to dig at the top, by which means the progress of the workmen will soon be impeded by accumulating rubbish, or the rushing in of water, it would be far preferable to commence on one side of the elevation which contains the material, having previously ascertained which way the rocks incline or dip, and gradually approach the quarry on this side; clearing away the dirt and superincumbent substances as low down as the nature of the ground will admit. In this manner, the mouths or openings of the quarries may be easily kept free, and the water carried off; at the same time, the materials may be operated upon and removed with the greatest facility. If the nature of the situation admits of the opening of a quarry in this manner, the more convenient method of working it is by gradations or steps. That is, the stone is first taken from the top to an uniform depth, for a considerable distance back; then another stratum or layer is removed, till it approaches within some distance of the first, when a third is begun, and so on; so that the quarry presents the appearance of steps, or horizontal planes one above the other. This method affords facilities for removing the stone or materials, without the aid of expensive machinery.

There is often a great difference in the quality of the material in the same quarry. Those portions which are nearest to the surface are sometimes mixed with foreign ingredients, that impair their value or render them useless.

The stones are obtained of suitable dimensions by blasting, by splitting with iron wedges set in a direct line, and driven with much force by a sledge or hammer. Advantage is often taken of natural fissures which are in straight lines, and often at right angles.

Granite, and the stones related to it, although of great hardness, will split very straight, by means of wedges. The pieces are afterwards wrought into the form to be used, either at the quarry, which diminishes the expense of transportation, or removed in a rough state, and thus used in building; or finished, as may be deemed expedient.

In working granite and materials of a similar nature, it is first lined, or marked into the form desired. The workman then forms the edge all round by means of a chisel and hammer, making it smooth and straight to the depth of one or two inches; he afterwards breaks off the larger portions with a hammer made in a peculiar form, and kept sharp; with this instrument he continues to take off the inequalities of the surface, till it has the requisite smoothness.

Sandstone, freestone, and materials of the like nature, being less hard than granite, are more easily wrought by a similar process. Some of them admit of a considerable degree of polish.

Marble and soapstone are taken from the quarries in large masses, and afterwards sawed, either by hand, or in mills constructed for the purpose, and then polished. (See *Marble* and *Soapstone.*) Slate, in some instances, is obtained by blasting. It is sometimes dug out by one set of men, split by another, and formed into slates by a third; for which purposes, flat crowbars, slate-knives, and axes are employed. It is often divided into three sorts, as firsts, seconds, and thirds, which vary in quality and price.

Sand and gravel are mostly dug out from the sides of banks, and other places; and but rarely obtained by sinking the quarries into the more level parts of the ground, though this method is sometimes practised. The materials are commonly raised, simply by digging with spades; and thrown into carts, in many cases, from the quarries or pits themselves.

The removal of materials from quarries is effected by means of inclined planes, of railways, or by various machines constructed for the purpose, such as the windlass, the pulley, &c., adapted in each instance to the situation of the quarry, and the circumstances of the case.

The Quincy stones are raised from their beds by the means of a windlass worked by a horse, and received upon cars, which run upon inclined railways, within a few feet of the quarry; from thence they are conveyed to the sea on a railway, and transported in various directions. By the descent of a loaded car on the inclined railway at the quarry, an empty car is drawn up.

The greatest difficulty incident to working quarries is that of *draining*, and freeing their bottom parts from injurious water; so that they may be in a fit state to be wrought with ease and advantage.

The most usual remedies resorted to in this difficulty are pumps worked by wind, by horse, steam, or other powers; but these often prove ineffectual in removing the water completely, and new quarries are opened near the old ones. But an attention to certain principles, in regard to the nature of the soil and the courses of subterraneous waters, may often lead to more cheap, expeditious, and effectual remedies.

It is now well understood, that most springs and subterraneous collections of water are formed and supplied from such grounds as lie higher than that of the places where the waters are met with, which, in consequence of their being of an open and porous nature, admit the rain and other sorts of moisture to filtrate and pass freely through them. These waters descend to great depths before they become impeded by some sort of impenetrable stratum, or layer of a solid or stony nature, as clay, or compact rock. It may happen, in sinking quarries, that beds of quicksand may be met with, which are so full of water, that to penetrate through them will be very difficult; and from a knowledge that the water proceeds from the porous ground that lies above them, it may be practicable to intercept and cut off the greater part of it before it reaches the sand-beds in the quarries, by the means of boring into and tapping the water at the *tails* of the banks of this nature, provided that the ground declines lower than the place where the sand is found in the quarries, which may be done at a trifling expense in comparison to the common remedies.

But in order to accomplish this intention, it will be necessary, in ascending from the quarry, to ascertain if, at the place higher on the declivity, any porous stratum, bed of rock, sand, or gravel, *tails* out, which may convey the water contained in it to the sand-bed, which is below in the works; and where any such is found, to cut and bore into it, in such a manner as to form a drain, that is capable of conveying off the water, which would otherwise have descended into the quarry.

But although this part of the business may have been accomplished, and the supply of water from the higher ground entirely cut off, a sufficient quantity to injure and inconvenience the working may yet continue to drain from the sides of the sand-beds, though they should happen to dip towards the lower ground; in which cases, however, this water may be drawn off readily to some particular point.

In order to effect this, it should be ascertained at what particular place in the low ground the sand terminates, or *tails* out, which is the best accomplished by means of proper levelling; and if there should be any appearance, in this place, of the water's having a natural outlet, it may, by making it into a deep drain, cause the water effectually to be drawn off. Where, however, there happens to be a deep, impervious layer of clay, or other matter of a similar nature, placed above or upon the termination or tail of the sand, the drain need only be cut down to it, or a little way into it, as by means of boring through it a ready and easy passage may be given to the whole of the water contained in the sand-bed or porous stratum.

It is of material importance to lay dry all such grounds as are situated higher, but contiguous to quarries, for the above-stated reasons; and it may in general be accomplished with but little difficulty and expense, by adopting the same principles and the same means.

This is the mode that is to be pursued in preventing the effects of the water, or cutting it off, when met with in sinking quarries. It proceeds on the principle of the dipping position of the strata, with the natural inclination of the land.

It frequently happens that a body of the same stone, which is of a close and compact nature, is found lying under one which has a more open and porous texture, with fissures and cracks in it, that are admissible of water, in the upper body or layer, in such a manner that none can pass through it to the inferior, or still deeper, open stratum or bed; and on sinking or cutting through this compact bed, another layer is met with, which is of so porous a nature as to admit the reception of any water that may come upon it. And sometimes a bed of gravel or sand is found under that of close stone, which, being capable of absorbing any water that may come upon it, is far better suited for the purpose of clearing the upper bed of stone from water than the stratum of open stone itself. Therefore, when this is ascertained to be the case, and the water is kept up by the second bed of stone, so as to be injurious to the working of the upper bed, and which will be equally so in working the second, the work may be greatly freed by boring through the close bed of stone, and letting the water down into the more porous one below, or into a stratum of dry sand or gravel, should there be such a one underneath it. But, instead of boring, the sinking of small pits through the close stone is a more effectual way of letting down the water.

In all such cases as these, boring or sinking pits through the solid stratum into a porous substance or layer underneath is the most advisable, and, at the same time, the least expensive, method that can be pursued.

## TABLE.

The following table shows the weight of granite stone, in pounds and hundredths, both in a cubical and cylindrical form; the dimensions being given. The first column of figures denotes a piece of stone to be 1, 2, 3, &c., inches square, or in diameter; each piece being 12 inches in length. Columns two and three are the mean weight of common stone; four and five, the weight of the Quincy stone; six and seven, the weight of a species of coarse granite, found at Sandy Bay, in Massachusetts.

| | | MEAN WEIGHT OF STONE IN GENERAL. | | QUINCY GRANITE. | | SANDY BAY GRANITE. | |
|---|---|---|---|---|---|---|---|
| | | Square. | Cylindric. | Square. | Cylindric. | Square. | Cylindric. |
| Estimated at one foot long. | 1 | 1.07 | .86 | 1.16 | .95 | 1.17 | .95 |
| | 2 | 4.33 | 3.45 | 4.65 | 3.80 | 4.68 | 3.80 |
| | 3 | 9.70 | 7.75 | 10.44 | 8.55 | 10.53 | 8.56 |
| | 4 | 17.33 | 13.80 | 18.56 | 15.20 | 18.72 | 15.21 |
| | 5 | 27.00 | 21.50 | 29.00 | 23.75 | 29.22 | 23.77 |
| | 6 | 38.10 | 31.00 | 41.76 | 34.20 | 42.12 | 34.23 |
| | 7 | 52.67 | 42.00 | 55.88 | 46.55 | 57.33 | 44.59 |
| | 8 | 69.00 | 55.00 | 74.24 | 60.80 | 74.88 | 60.86 |
| | 9 | 86.67 | 69.65 | 83.96 | 76.95 | 94.77 | 77.03 |
| | 10 | 107.33 | 86.00 | 116.00 | 95.00 | 117.00 | 95.10 |
| | 11 | 130.00 | 104.00 | 140.36 | 114.95 | 141.57 | 115.07 |
| | 12 | 155.00 | 124.00 | 167.04 | 136.80 | 168.48 | 136.94 |
| Estimated at five feet long. | 1 | 5.35 | 4.30 | 5.80 | 4.75 | 5.85 | 4.75 |
| | 2 | 23.65 | 17.25 | 23.20 | 19.00 | 23.40 | 19.40 |
| | 3 | 48.50 | 38.75 | 52.20 | 42.75 | 52.65 | 42.80 |
| | 4 | 86.65 | 69.00 | 92.80 | 76.00 | 93.60 | 75.05 |
| | 5 | 135.00 | 107.50 | 145.00 | 118.75 | 146.10 | 118.85 |
| | 6 | 190.50 | 155.00 | 200.80 | 171.00 | 210.00 | 171.15 |
| | 7 | 263.35 | 310.00 | 379.20 | 232.75 | 286.65 | 222.95 |
| | 8 | 345.00 | 275.00 | 371.20 | 304.00 | 374.40 | 304.30 |
| | 9 | 433.35 | 348.00 | 419.80 | 384.75 | 473.85 | 385.15 |
| | 10 | 536.65 | 430.00 | 580.00 | 475 00 | 585.00 | 475.50 |
| | 11 | 650.00 | 520.00 | 701.80 | 574.75 | 707.85 | 575.35 |
| | 12 | 775.00 | 620.00 | 835.20 | 680 00 | 842.40 | 684 70 |
| Estimated at ten feet long. | 1 | 10.70 | 8.60 | 11.60 | 9.50 | 11.70 | 9.50 |
| | 2 | 43 30 | 34.50 | 46.40 | 38.00 | 56.80 | 38.00 |
| | 3 | 97.70 | 77.50 | 104.40 | 85.50 | 105.30 | 85.60 |
| | 4 | 173.30 | 138.00 | 185.60 | 152.00 | 187.20 | 152.10 |
| | 5 | 270.00 | 215.00 | 290.00 | 237.50 | 292.20 | 237.70 |
| | 6 | 381.00 | 310.00 | 417.60 | 342.00 | 421.20 | 342.30 |
| | 7 | 526.70 | 420.00 | 558.40 | 465.50 | 573.30 | 445.90 |
| | 8 | 690.00 | 550.00 | 742.40 | 608.00 | 748.80 | 608.60 |
| | 9 | 866.70 | 696.00 | 839.60 | 769.50 | 947.70 | 770.30 |
| | 10 | 1073.00 | 860.00 | 1160.00 | 950.00 | 1170.00 | 951.00 |
| | 11 | 1300.00 | 1040.00 | 1403.00 | 1149.00 | 1415.70 | 1150.70 |
| | 12 | 1550.50 | 1240.00 | 1670.40 | 1368.00 | 1684.80 | 1369.40 |

*Mean Weight of a Cubic Foot of Stone, and the Weight it w sustain with Safety.*

| | Mean Weight. | Weight it will sustain. |
|---|---|---|
| **Granite.** | | |
| Sandy Bay Stone, | 148.48 lbs. | 197,000 lbs. |
| Quincy do. | 167.04 " | 156,000 " |
| Concord do. | 159.00 " | 149,000 " |
| Frankfort do. | 162.00 " | 148,000 " |
| **Marble.** | | |
| White New York, | 173 lbs. | 85,000 lbs. |
| New Haven Variegated, | 175 " | 89,000 " |
| Pennsylvania Dove, | 170 " | 86,000 " |
| Thomaston Blue, | 179 " | 90,000 " |
| Vermont Dove, | 168 " | 86,000 " |
| **Sandstone or Freestone.** | | |
| Connecticut, | 164 lbs. | 118,000 lbs. |
| North River, | 156 " | 108,000 " |
| Potomac, | 153 " | 98,000 " |

## TABLE OF CYLINDRICAL MEASURES.

Designed for the computation of the contents of lead pipes, from one inch diameter to three and upwards; also, cisterns of ten feet diameter and under; the quantity and weight of water in pumps, suction pipes, &c., from one inch diameter and upwards.

| Inches Diameter. | Cubic feet and parts. | Ale gallons and parts. | Wine gallons and parts. | Weight of water, in lbs. and parts. | Dry bushels and parts. |
|---|---|---|---|---|---|
| 1 | .0055 | .033 | .04 | .34 | .0044 |
| 2 | .0218 | .134 | .16 | 1.36 | .0175 |
| 3 | .0491 | .301 | .37 | 3.06 | .0394 |
| 4 | .0873 | .534 | .65 | 5.45 | .0700 |
| 5 | .136 | .835 | 1.02 | 8.52 | .110 |
| 6 | .196 | 1.20 | 1.47 | 12.27 | .158 |
| 7 | .267 | 1.64 | 2.00 | 16.70 | .215 |
| 8 | .349 | 2.14 | 2.61 | 21.82 | .281 |
| 9 | .442 | 2.71 | 3.30 | 27.61 | .355 |
| 10 | .545 | 3.34 | 4.08 | 34.09 | .438 |
| 11 | .660 | 4.04 | 4.94 | 41.25 | .530 |
| 12 | .785 | 4.81 | 5.88 | 49.09 | .631 |
| 24 | 3.14 | 19.25 | 23.52 | 196.36 | 2.521 |
| 36 | 7.07 | 43.30 | 52.92 | 441.79 | 5.68 |
| 48 | 12.57 | 77.00 | 94.08 | 785.44 | 10.10 |
| 50 | 13.64 | 83.55 | 102.00 | 852.21 | 11.00 |
| 60 | 19.64 | 120.30 | 146.88 | 1227.19 | 15.78 |
| 72 | 28.28 | 173.20 | 211.51 | 1767.15 | 22.72 |
| 84 | 38.49 | 235.81 | 287.88 | 2405.28 | 30.92 |
| 96 | 50.27 | 308.00 | 376.01 | 3141.59 | 40.39 |
| 108 | 63.62 | 389.79 | 475.89 | 3976.08 | 51.12 |
| 120 | 78.54 | 481.25 | 587.52 | 4903.74 | 63.11 |

N. B. If the diameter should fall between any of the numbers in the first column, the mean proportional contents may be found by adding the two contents between which it falls, and dividing

by two. Suppose it falls between 108 and 120 of the diameters, required the wine gallons in 114 inches, or 9 feet 6 inches diameter, which falls between 587.52
and 475.89
2) 1063.41
Answer, 531.70½

Or if between 60 and 72, say 64 inches, or 5 feet 4 inches ; one third of 12 is 4 ; then required the cubic feet and parts.

| | |
|---|---|
| | 28.28 |
| Subtract | 19.64 |
| Divide by 3) | 8.64 |
| | 2.88 |
| Add | 19.64 |
| Answer, | 22.52 |

Any depth may be found, by multiplying by the depth any of the numbers in the contents; as, required the number of ale gallons in 24 inches diameter, at 6 feet deep. $19.25 \times 6 = 115.50$, Ans.

## A TABLE

For the computation of the weight of wrought iron of different dimensions, from ⅛ of an inch to 5 inches square ; also, round, from ⅛ of an inch to 5 inches diameter. The third and fourth columns for flat bars, from 1¼ to 6 inches wide, from ⅛ to 5 inches thick ; each dimension estimated at one foot in length.

| Square Bars. | | | | | Round Iron. | | | | | Flat Bars. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In. | 8ths. | lbs. | oz. | dr. | In. | 8ths. | lbs. | oz. | dr. | In. 8ths. | lbs. | oz. | dr. | In. 8ths. | lbs. | oz. | dr. |
| | 1 | 0 | 1 | 12 | | 1 | 0 | 0 | 14 | 1¼×1 | 0 | 4 | 6 | 2½×2 | 2 | 3 | 0 |
| | 2 | 0 | 3 | 8 | | 2 | 0 | 1 | 12 | 2 | 0 | 8 | 12 | 3 | 3 | 4 | 8 |
| | 3 | 0 | 7 | 14 | | 3 | 0 | 7 | 0 | 3 | 1 | 10 | 4 | 4 | 4 | 6 | 0 |
| | 4 | 0 | 14 | 0 | | 4 | 0 | 11 | 0 | 4 | 2 | 3 | 0 | 5 | 5 | 7 | 8 |
| | 5 | 1 | 5 | 14 | | 5 | 1 | 1 | 3 | 5 | 2 | 11 | 12 | 6 | 6 | 9 | 0 |
| | 6 | 1 | 15 | 8 | | 6 | 1 | 8 | 12 | 1½×2 | 1 | 5 | 0 | 7 | 7 | 10 | 8 |
| | 7 | 2 | 10 | 14 | | 7 | 2 | 1 | 11 | 3 | 1 | 15 | 8 | 8 | 8 | 12 | 0 |
| 1 | 0 | 3 | 8 | 0 | 1 | 0 | 2 | 12 | 0 | 4 | 2 | 11 | 0 | 2¾×3 | 3 | 9 | 12 |
| | 1 | 4 | 6 | 14 | | 1 | 3 | 7 | 11 | 5 | 3 | 4 | 8 | 4 | 4 | 13 | 0 |
| | 2 | 5 | 7 | 8 | | 2 | 4 | 4 | 12 | 1¾×2 | 1 | 8 | 8 | 5 | 6 | 0 | 4 |
| | 3 | 6 | 9 | 14 | | 3 | 5 | 3 | 3 | 3 | 2 | 4 | 12 | 6 | 7 | 3 | 8 |
| | 4 | 7 | 14 | 0 | | 4 | 6 | 3 | 0 | 4 | 3 | 1 | 0 | 7 | 9 | 10 | 0 |
| | 5 | 9 | 3 | 14 | | 5 | 7 | 4 | 3 | 5 | 3 | 13 | 4 | 3×3 | 3 | 15 | 0 |
| | 6 | 10 | 11 | 8 | | 6 | 8 | 6 | 12 | 6 | 4 | 9 | 8 | 4 | 5 | 4 | 0 |
| | 7 | 12 | 4 | 14 | | 7 | 9 | 10 | 11 | 7 | 5 | 5 | 12 | 5 | 6 | 9 | 0 |
| 2 | 0 | 14 | 0 | 0 | 2 | 0 | 11 | 0 | 0 | 8 | 6 | 2 | 0 | 4×3 | 5 | 4 | 0 |
| | 1 | 15 | 12 | 14 | | 1 | 12 | 6 | 11 | 2 ×2 | 1 | 12 | 0 | 4 | 7 | 0 | 0 |
| | 2 | 17 | 11 | 8 | | 2 | 13 | 14 | 12 | 3 | 2 | 10 | 0 | 5 | 8 | 12 | 0 |
| | 4 | 21 | 14 | 0 | | 3 | 15 | 8 | 3 | 4 | 3 | 8 | 0 | 8 | 14 | 0 | 0 |
| | 6 | 26 | 7 | 8 | | 4 | 17 | 3 | 0 | 5 | 4 | 6 | 0 | 5×3 | 6 | 9 | 0 |
| 3 | 0 | 34 | 0 | 0 | | 5 | 18 | 15 | 3 | 6 | 5 | 4 | 0 | 4 | 8 | 12 | 0 |
| | 2 | 36 | 15 | 8 | | 6 | 20 | 12 | 12 | 7 | 6 | 2 | 0 | 5 | 10 | 15 | 0 |
| | 4 | 42 | 14 | 0 | | 7 | 22 | 11 | 11 | 8 | 7 | 0 | 0 | 6 | 13 | 2 | 0 |
| | 6 | 49 | 3 | 8 | 3 | 0 | 24 | 12 | 0 | 2¼×2 | 1 | 15 | 8 | 6×3 | 7 | 14 | 0 |
| 4 | 0 | 54 | 0 | 0 | 4 | 0 | 44 | 0 | 0 | 3 | 2 | 15 | 4 | 4 | 10 | 8 | 0 |
| | 2 | 63 | 2 | 8 | | 2 | 49 | 11 | 12 | 4 | 3 | 15 | 0 | 5 | 13 | 2 | 0 |
| | 4 | 70 | 14 | 0 | 5 | 0 | 68 | 12 | 0 | 5 | 4 | 14 | 12 | | | | |
| | 6 | 78 | 15 | 8 | | | | | | | | | | | | | |
| 5 | 0 | 87 | 8 | 0 | | | | | | | | | | | | | |

# RULES

## FOR MEASURING HAMMERED GRANITE STONE,

ADOPTED APRIL, 1829.

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## PREAMBLE.

To prevent misunderstanding between the stonecutters, the masons, and their employers, in relation to the admeasurement of hammered granite stone, it was deemed expedient that a meeting be called of those engaged in the business, to endeavour to agree upon some uniform system, that shall be equally intelligible to all parties; said meeting was held in March last, when a committee of eleven persons was chosen, to take the subject into consideration, and report at a subsequent meeting. At a meeting in April, said committee reported, that they had attended to the duty assigned them, and, after mature deliberation, have agreed on the following rules, which, if adopted, will, in their opinion, greatly promote the interest as well as the harmony of all concerned in the business, whether purchaser or vender; at which meeting said rules were adopted by the unanimous vote of all present, who then affixed their signatures to the same, since which others have subscribed their names.

*Boston*, *May* 17, 1829.

## RULES.

SECTION 1. ASHLAR STONES are to be measured on their fronts, quoin-heads, and reveals against doors, windows, and recesses.

SECT. 2. HEADERS or binders, that make the thickness of the wall, are to be measured as ashlar-work, adding their beds, or builds.

SECT. 3. DOUBLE-HEADED QUOINS, not less than nine inches each head, are to be measured as ashlar-work, adding their beds, or builds.

SECT. 4. WINDOW-CAPS, for ashlar-work, are to be measured on their fronts, under sides that show, and reveals.

SECT. 5. WINDOW-SILLS, for ashlar-work, are to be measured on their tops and fronts, the whole thickness of their rise, and half their under sides.

SECT. 6. BELT STONES, for ashlar or brick-work, from seven to nine inches rise, and the usual thickness of ashlar-work, are to be cast at the rate of a superficial foot to each foot in length.

SECT. 7. ARCH STONES, in ashlar-work, are to be measured their extreme lengths by their extreme widths, adding the returns and reveals.

SECT. 8. ASHLAR STONES, for pediments or gable ends of buildings, and other similar purposes, are to be measured their extreme lengths by their extreme widths.

SECT. 9. PLINTHS are to be measured on all parts that show, and half the rough-hammered parts.

SECT. 10. PILASTERS are to be measured on their fronts, returns, and reveals.

SECT. 11. IMPOSTS are to be measured on their fronts, ends, and beds, or builds.

SECT. 12. POSTS or CAPS are to be measured on four sides, and the ends of caps that show.

SECT. 13. POSTS in or out of square are to be measured on four sides, squaring from their extreme points.

SECT. 14. DOOR-SILLS, under posts, are to be measured on their tops, fronts, and ends, and half the parts hammered under the ends.

SECT. 15. WINDOW-SILLS, between posts, are to be measured on their tops, under sides, and their whole rise.

SECT. 16. ARCH CAPS and BLOCKS, that make the thickness of the wall, are to be measured on four sides, the extreme lengths by their extreme widths.

SECT. 17. BELT STONES, that make the thickness of the wall, are to be measured on their fronts, beds, and builds, and ends that show.

SECT. 18. COURSES OF STONES, that make the thickness of the wall, are to be measured on their fronts, beds, and builds.

SECT. 19. DOOR-STEPS are to be measured on their tops, fronts, and laps, and the ends that show, which ends are to be measured at the rate of a superficial foot to each foot on the width.

SECT. 20. RETURNS for steps, from six to ten inches rise, are to be measured at the rate of a superficial foot to each foot in length.

SECT. 21. PLATFORM STONES are to be measured as steps; when two or more are required, half the edges for joints are to be added.

SECT. 22. SPIRAL STEPS are to be measured their extreme length by their extreme width, rise, and laps, and ends that show.

SECT. 23. FENCE STONES are to be measured on their fronts, tops, and inside, where hammered, and ends that show.

SECT. 24. POSTS, that stand in the ground, are to be measured on four sides and tops, and half measurement of the rough parts in the ground, according to the dimensions of the hammered parts.

SECT. 25. CELLAR-DOOR CURBS are to be measured on their tops and inside, or rise, the whole length of each stone; the rabbets are to be measured the length of each stone by the running foot.

SECT. 26. CELLAR-WINDOW CURBS are furnished by the piece.

SECT. 27. WELL CURBS are to be measured on the outside and tops, where hammered with the jogs and corresponding ends.

SECT. 28. SESSPOOL CURBS are to be measured as Cellar-door Curbs.

SECT. 29. GUTTER STONES are to be measured on the top side by the superficial foot; Cutting Gutters to be charged extra.

SECT. 30. EDGE STONES are to be measured by the running foot, double measure when circular.

SECT. 31. CUTTING SCROOLS, JOGS, RABBETS, GROOVES, GUTTERS, and DRILLING HOLES are extra work, and do not add to or diminish from the measurement of the work.

SECT. 32. VAULT STONES are to be measured on three or four sides, as may be hammered, and the ends that show. Floor and Ceiling Stones, more than nine inches in thickness, are to be measured on one side and two edges, and the ends that show; when nine inches or less thickness, on one side and ends that show.

SECT. 33. All STONES not included in the foregoing specifications, on account of their irregular form or unfrequent use, should be measured as nearly as possible according to the rules applying to those which resemble them.

SECT. 34. Those which differ in all respects must be furnished by the piece.

SECT. 35. The two foregoing observations apply to Ornamental Work, the parts of which are so minute, and generally of such complicated forms, that no system of rules sufficiently short and comprehensive can with any utility be adopted; with regard, however, to two or three parts of Ornamental Work, in common use, it may be well to state, that Cornice is usually furnished by the running foot; Bases, Columns, and Capitals, by the piece.

Sect. 36. All Circular Work to be charged extra, and the mode of measurement should be agreed upon at the time said work is contracted for.

William Austin,
Gridley Bryant,
Benjamin Blaney,
Jacob Bacon,
William Crehore,
Samuel Currier,
Levi Cook,
Conrad C. Carleton,
James C. Ewer, Jr.,
George H. Ewer,
Joseph Glass,
Ephraim Harrington,
Thomas Hollis,
Charles G. Hall,
Samuel R. Johnson,
Nathaniel Jewett,
Sewall Kendall,
Allen Litchfield, Jr.,
Ward Litchfield,
Francis Lawrence,
James McAllaster,
Caleb Metcalf,
Samuel Marden,
Luther Munn,
Jonathan Newcomb,
Cushing Nichols,
Alexander Parris,
James Page,
William Packard,
Lot Pool,
Joseph Richards,
John Redman,
Wyatt Richards,
Alanson Rice,
Edward Shaw,
Zephaniah Sampson,
Franklin Sawyer,
Asa Swallow,
James S. Savage,
Amos C. Sanborn,
Job Turner,
Joseph Tilden,
Charles Wells,
William Wood,
Mordecai L. Wallis,
Richard Witherell,
Henry Wood,
Jeremiah Wetherbee,
Salmon Washburn.

## CHAPTER II.

### SECTION I. — Clay.

The substances included under this term are mixtures of silex, or the ingredient of the common gun-flint and alumine; they sometimes contain other earths, or metallic oxyds, by the latter of which some varieties are highly colored. Their hardness is never great; they are easily cut by a knife, may in general be polished by friction with the finger-nail, and are usually soft to the touch. When immersed in water they crumble more or less readily, and become minutely divided. Many clays, when moistened, yield a peculiar odor, called argillaceous; but this quality appears to be owing to the presence of metallic oxyds, as perfectly pure clays do not possess it.

The substances which are properly termed clays may, by a due degree of moisture and proper management, be converted into a paste more or less tenacious and ductile, which constitutes the basis of several kinds of pottery. It possesses a greater or less degree of unctuosity, and is capable of assuming various forms without breaking. This argillaceous paste, when dried, becomes in some degree hard and solid, and, by exposure to a sufficient degree of heat, may be made to assume a stony hardness.

Clays have a strong affinity for water; hence the avidity with which they imbibe it; hence, also, they adhere more or less to the tongue or lips.

Clay, when composed of only silex and alumine, in any proportions, is infusible in a furnace, and even when somewhat impure it resists a degree of heat without melting. But the presence of other earths, particularly of lime, or of a large quantity of oxyd of iron with a little lime, renders it fusible. By exposure to heat it diminishes in bulk, and loses somewhat of its weight by the escape of water.

Although clay is essentially composed of silex and alumine, these ingredients exist in various proportions. In most cases silex predominates, being in the proportion of two, three, or even four parts to one of alumine; sometimes the proportions are nearly equal, and in some cases the alumine predominates. The power of alumine to impress its character on the compound, although present in less proportion than the silex, probably arises from a greater minuteness of its particles.

The color of clay may proceed from oxyd of iron, or from some bituminous or vegetable matter. Hence some colored clays, when exposed to heat, become white by the destruction of their combustible ingredients, while others suffer merely a change of color, by the action of oxygen on the iron. The purer clays are white or gray, and suffer little or no change by the action of fire.

The varieties of clay are numerous; the purest kinds are extensively used in the manufacture of porcelain ware; and those that are less pure are burnt into stone ware and bricks.

The common clays may be divided, in regard to their utility, into three classes, the *Unctuous*, *Meagre*, and *Calcareous.*

The unctuous contains, in general, more alumine than the meagre, and the siliceous ingredient is in finer grains; when burnt it adheres strongly to the tongue, but its texture is not visibly porous. When containing little or no oxyd of iron, it burns to a very good white color, and is very infusible; pipes are made of it, and it forms the basis of the white Staffordshire ware. If it contains oxyd of iron sufficient to color it red, when baked, it becomes much more fusible, and can only be employed in manufacturing the coarser kinds of pottery.

Meagre clay is such, as, when dry, does not take a polish from rubbing it with the nail; it feels gritty between the teeth, and the sand which it contains is in visible grains. When burnt without addition, it has a coarse granular texture, and is employed in the manufacture of bricks and tiles.

Calcareous clay effervesces with acids, is unctuous to the touch, and always contains iron enough to give it a red color when baked. It is much more fusible than any of the preceding kinds, and is only employed in brick-making. By judicious burning it may be made to assume a semi-vitreous texture, and bricks thus made are very durable.

Clays are very abundant in nature, and contribute the most to the wants and conveniences of man of all the earthy minerals.

## SECTION II. — Brick-making.

The clay for the purpose of making bricks should be dug in the autumn, and piled in solid heaps. During the winter it should be broken up, and exposed in such masses, from day to day, as to become thoroughly penetrated by the frost.

In the spring the clay is to be broken into small pieces, and shovelled over, in order to expel the frost. After this is done, it is thrown into pits, and mixed with fine sand and a suitable proportion of water; the sand should be clear, free from lumps of marl and saline particles, — siliceous sand is to be preferred, — and the water must be fresh. The ingredients are to be worked over by the means of the shovel, treading, or the wheel, till they are properly incorporated, and are of a suitable consistency. In this way they are prepared for the striker's bench.

In preparing for a brick-yard, the surface of the ground should be cleared and levelled; a coat of sand, two or three inches in depth, is to be put upon it, and rendered as hard and as smooth as is practicable, by passing a heavy roller several times over it when wet. After this a thin layer of sand is sifted upon the surface, and a wooden scraper passed over it, in order to render it as smooth and even as possible. The yard should be of a size sufficient to contain the bricks that may be struck in two days.

Brick-moulds are commonly made to contain six bricks each. The striker is prepared with two moulds, and a trough of water. When the prepared clay is shovelled on to the striker's table, he takes his mould from the trough of water, adjusts it on a thin, level board bottom, and with his hands wet, to prevent adhesion, strikes from the pile of mortar or prepared clay a quantity a little more than sufficient to fill one of the apertures of the mould, which he drops into it with considerable force, and presses it firmly down; he then strikes the surplus off with his hand, and thus proceeds till all the apertures of the mould are filled.

A second person (called the carrier) now takes the full mould from the striker's table to another part of the brick-yard, and puts it down bottom upwards. The bottom board is then drawn off diagonally, in order to preserve the edges of the bricks entire, the mould is raised, and the bricks left on the sand to dry. The carrier returns the empty mould to the striker's trough, takes the second full mould, and deposits the bricks as before. The bricks are thus exposed in ranges till they are so dry as not to be easily defaced; they are then placed upon their edges, and remain till they are dry enough to be put into hacks. The hacks are composed of alternate layers of bricks; the first layer is called *stretcher*, and the second *header;* interstices or spaces are left between the bricks of from three eighths to half an inch, so that the air may have a free circulation between them.

The bricks ought to remain in this situation till they are dry enough to go into the kiln, or at least for six or eight weeks of dry weather. The hacks may be of the thickness of three or four bricks placed lengthwise, and six or eight feet in height. They are to be protected from storms by sheds erected for the purpose.

In forming bricks into a kiln, they are laid in benches, with arches, or apertures for the fuel. A bench is formed in this manner. Courses of brick, or the stretchers, are laid lengthwise; and across the stretchers, or at right angles with them, are laid other courses, or headers; interstices are left between the bricks from one fourth to one half an inch in thickness. The stretchers and headers alternate with each other, and four courses of them form a bench. Between every two benches, there is a space left, two bricks' length in breadth, for arches. The arches are formed by the gradual projection of the courses in the two benches, about as far as the eighth course, where the courses of the benches, on each side of the space, meet, at the distance, generally, of thirty-two inches from the ground. The benches are commonly raised to the height of seven or eight feet. Thus the benches and arches alternate with each other, till the number is increased, as it may be deemed expedient. The bricks in the bench are placed on their edges, and care should be taken to preserve throughout the interstices between their sides so that the heat may percolate. At the top of the kiln, the outside walls should have an inclination inwards, of about one foot in seven of perpendicular height. The kiln is faced by refuse or unburnt bricks, laid up in clay mortar, extending round the whole exterior of the kiln, the thickness of the width of a single brick. The mouths of the arches are to be left open, and flat stones prepared for closing them while the kiln is in the progress of burning.

The moulds used in the vicinity of Boston are commonly eight and three eighths inches in length, two and one eighth in thickness, and four and one half in width; and bricks, when burnt, vary from eight to seven and three fourths inches in length, and are about four inches in width, and two in thickness, according to the length of time and the degree of heat to which they have been exposed.

The burning is commenced with a moderate heat, in order first to expel the moisture. When this is done, the smoke changes from a great degree of blackness to a thin, transparent glimmering.

Then the intensity of the heat is increased to as great a degree as the material will bear, without being fused, which is continued till a contraction, or shrinkage, takes place at the top of the kiln, and at the ends of the arches opposite to those in which the fuel is placed. When this is the case, it is necessary to close the mouths of the arches at which the fuel has been inserted, and to put it in at the mouths opposite. At the close of the process of burning, the arches are filled with hard wood and then closed, and the kiln is suffered to remain thus till the bricks are sufficiently cool for handling, before they are exposed to the air.

A machine has recently been patented and put in operation in this vicinity for preparing the materials for brick, which seems to possess many advantages over the common method. The machine consists of a wheel for mixing the mortar, and apparatus for filling the moulds, and is worked by horse or steam power. It possesses, among others, the following advantages: that of pulverizing the clay more thoroughly, and producing a more homogeneous and compact paste, and in consequence the bricks are less liable to crack in the operation of drying or burning, and, by being more firmly pressed into the moulds, they are less liable to absorb moisture from the atmosphere, and are rendered smoother; and as less water is required by this mode in making the paste, the bricks do not require the same length of time in drying, while they are subject to shrink less in burning than in the common method; and lastly, much time and labor are saved in the operation.

### SECTION III. — Faced or Pressed Bricks.

These bricks are used to form the facing of walls in the better kind of structures, and are finished in a machine. The roughness and change of form, to which common bricks are liable, is owing in part to the evaporation of a portion of the water which the clay contains. To remedy the difficulty arising from this cause, the bricks, after being moulded in the common manner, are exposed to the sun till they are nearly dried, retaining, however, sufficient plasticity to be still capable of a slight change of form. The moulds, however, are somewhat larger than those of the common bricks, in order that the bricks, when pressed, may be of a sufficient size. The press machine is usually made of cast iron, and contains a number of moulds arranged in a circle or otherwise, so that the power is applied to them in succession, and the bricks pressed with rapidity. The mould is of sufficient thickness to resist about a ton's weight applied to the top of a follower. The follower is fitted as near as practicable to the inner side of the mould, and kept in a proper position to be forced through, when the moulds are removed from their beds. This is done by the means of a wheel or slide, to which the mould is attached. The bricks, being pressed, are received on a carrying-board.

The force is applied for pressing the bricks by the means of a double purchase lever, or by the revolution of a wheel with rollers running on an oblique plane.

In this manner about five thousand bricks may be pressed off in a day, by the labor of two men and a horse.

The pressed bricks are of a superior quality in point of durability and elegance. They form a wall with a surface of great smoothness, and when carefully laid produce a pleasing effect. These bricks are durable from their hardness and smoothness, being less liable to decomposition from the action of the atmosphere.

A patent was obtained in England, about the year 1795, by Mr. Cartwright, for an improved system of making bricks, of which the following extract will furnish all necessary information.

"Imagine a common brick, with a groove on each side down the middle, rather more than half the width of the side of the brick; a shoulder will thus be left on each side of the groove, each of which will be nearly equal to one quarter of the width of the side of the brick, or to one half of the groove or rabbet. A course of these bricks being laid shoulder to shoulder, they will form an indented line of nearly equal divisions, the grooves being somewhat wider than the adjoining shoulders, to allow for the mortar or cement. When the second course is laid on, the shoulders of the bricks which compose it will fall into the grooves of the first course, and the shoulders of the first course will fit into the grooves of the second, and so with every succeeding course. Buildings constructed of these bricks will require no bond timbers, as an universal bond runs through the whole building, and holds all the parts together; the walls of which will neither crack nor bilge without breaking through themselves. When bricks of this construction are used for arches, the sides of the grooves should form the radii of a circle, of which the intended arch is a segment. In arch work the bricks may either be laid in mortar or dry, and the interstices afterwards filled up by pouring in lime, putty, plaster of Paris, &c. Arches of this kind, having any lateral pressure, can neither expand at the foot or spring at the crown; consequently they need no abutments; neither will they need any superincumbent weight on the crown to prevent them from springing up. The centres may also be struck immediately, so that the same centre, which never need be many feet wide, may be regularly shifted as the work proceeds. But the most striking advantage attending this invention is the security it affords against fire; for, from the peculiar properties of this kind of arch, requiring no abutments, it may be laid upon or let into common walls, no stronger than what are required for timbers, so as to admit of brick floorings."

## SECTION IV. — Brick Masonry.

The use of bricks in building may be traced to the earliest ages, and they are found among the ruins of almost every ancient nation. The earliest edifices of Asia were constructed of bricks, dried in the sun and cemented with bitumen. Of this material was built the ancient city of Nineveh. The walls of Babylon, some of the ancient structures of Egypt and Persia, the walls of Athens, the rotunda of the Pantheon, the Temple of Peace, and the Thermæ, at Rome, were all of brick. The earliest bricks were never exposed to great heat, as appears from the fact that they contain reeds and straw, upon which no mark of burning is visible. These bricks owe their preservation to the extreme dryness of the climate in which they remained, since the earth of which they were made often crumbles to pieces when immersed in water, after having kept its shape for more than two thousand years. This is the case of some of the Babylonian bricks, with inscriptions in the arrow-headed character, which have been brought to this country. The ancients, however, at a later period, burnt their bricks, and it is these chiefly which remain at the present day. The antique bricks were larger than those employed by the moderns, and were almost universally of a square form. Those of Rome appear to have been of three different sizes; the largest were about twenty-two inches square, and two and one fourth inches thick; the second size sixteen and one half inches square, and from one and one half to two inches thick; the smallest size about seven and one half inches square, and one and one half inches thick. In order to secure more effectually the facing with rubble, the Romans placed in their walls, at intervals of every three or four feet, two or three courses of the larger brick. (See *Plate* 22, *Fig*. 12.) The larger bricks were used in the formation of arches, and in the openings of buildings.

The bricks of the Greeks were commonly cubical and of different sizes. One size was a foot on all sides, another kind fifteen inches; the former was chiefly used in the construction of private, and the latter in public edifices. There was a third kind, a foot square and six inches thick, and a fourth kind, fifteen inches square and seven and a half inches thick; these last two kinds were called half-bricks, and were used for the purpose of better effecting the construction of a bond. (See *Plate* 22, *Fig*. 3.) They also employed, as well as the Romans, another size, for ornamental walls, called net-work. (See *Plate* 22, *Fig*. 13.) This net-work had a beautiful appearance, but was liable to crack; in consequence, according to Palladio, there are no ancient specimens of this kind remaining. Vitruvius, however, states the form of these bricks to have been a parallelogram, six inches wide, and from twelve to twenty-four inches long.

The baked bricks of the ancients were generally made of two parts of earth and one of cinders, well tempered together. They were taken from the moulds and left to dry in the sun for several days, and afterwards placed in a large furnace, ranged one over another, at some distance apart; the spaces between were filled with plaster, or a sort of strata of fine coal.

Besides bricks made of clay, the ancients also employed a kind of factitious stone, composed of a calcareous mortar. They were also in the habit of using bricks and stones, both rubble and wrought, in the same wall.

In a rubble wall, three courses of bricks were laid at intervals of two or three feet, for the purpose of binding the mass together; the angles were also supported by piers of stone or bricks. (See *Plate* 22, *Fig* 11.)

In buildings of more magnificence, (see *Plate* 22, *Fig*. 12,) the rubble was concealed in the wall. The bottom of the wall was formed of six courses of large bricks, then courses of smaller bricks were laid up to the height of three feet. Then the wall was bound again with three courses of large bricks, and so on. Examples of this kind of wall still remain in the Pantheon, and Warm Baths of Dioclesian.

### SECTION V. — Tiles.

Tiles are plates of burnt clay resembling bricks in their composition and manufacture, and used for the covering of roofs. They are necessarily made thicker than slates, or shingles, and thus impose a greater weight upon the roofs. Their tendency to absorb water promotes the decay of the wood-work beneath them.

Tiles are usually shaped in such a manner that the edge of one tile receives the edge of that next to it, so that water cannot percolate between them. Tiles, both of burnt clay and marble, were used by the ancients, and the former continue to be employed in various parts of Europe. Floors, made of flat tiles, are used in many countries, particularly in France and Italy.

### SECTION VI. — Compact Limestone.

The uses and geological characters of this substance render it peculiarly interesting. The term *compact*, however, as applied to this stone, must be received with some latitude; for, although its texture is often very close and compact, sometimes like that of wax, yet in other instances it is loose and earthy.

Among the numerous colors of compact limestone, the most frequent are the various shades of gray, such as smoke-gray, yellowish-gray, bluish-gray, reddish and greenish-gray; it is also seen grayish-white, grayish-black, flesh-red, with some deep tints of red and yellow; several of these colors often occur in the same fragment, which are distinguished by the epithet of *marbled.*

It usually occurs in extensive, solid, compact masses, whose fracture is dull and splintery, or even, and sometimes conchoidal. It is sometimes traversed by minute veins of calcareous spar, which reflect a little light; and some compact limestones are also slaty. Its hardness is somewhat variable. Its specific gravity usually lies between 2.40 and 2.75. It is opaque and more or less susceptible of a polish.

Compact limestone is seldom, perhaps never, a pure carbonate; but contains from two to twelve per cent. of silex, alumine, and the oxyd of iron, on the last of which its diversified colors depend. In fact, by increasing the proportion of argillaceous matter, it passes into marl. Some limestones, which effervesce considerably with an acid, are still so impure, that they melt rather than burn into lime.

The uses to which compact limestone is applied are various; it is principally employed as a building stone, and burnt for making lime and mortar; nor is it less important to the agriculturist as a manure, to the miner as a flux for the reduction of ores, to the soap-boiler, to the tanner, &c. It is a substance very abundantly diffused throughout the globe.

It is from compact limestone, that lime, so extensively used in the arts, is chiefly obtained; pure white marble, or limestone, undoubtedly furnishes the best lime, though but little superior to that obtained from gray, compact limestone.

## SECTION VII. — The Burning of Lime.

This is a process by which limestone, marble, shells, &c., are converted into lime by means of heat, in kilns properly constructed for the purpose. By the application of heat to any of these substances, their carbonic acid is driven off, and leaves the lime in a powder.

The calcination of limestone may be effected by wood, coal, or peat, as fuel; but the heat should not much exceed a red heat, unless the stone employed be nearly a pure carbonate. The fuel is placed in layers, alternately with those of the stones, or calcareous materials in the kilns, and the process of burning continued for any length of time, by repeated applications of fuel and the calcareous materials at the top; the lime being drawn out occasionally from below, as it is burnt.

Fossil or mineral coal is supposed to be the most convenient and suitable material for effecting this business, where it can be procured plentifully, and at a sufficiently cheap rate; as it burns the stone or other calcareous matter more perfectly, and of course leaves fewer cores in the calcined pieces than when other sorts of fuel are employed for the purpose.

Peat, also, is highly recommended, for its cheapness and uniformity of heat. When coal is used, the limestones are liable, from excessive heat, to run into solid lumps, which may be avoided by the use of peat, as it keeps them in an open state, and admits the air freely.

Count Rumford, with his usual attention to economy in fuel and in the expense of caloric, has invented an oven for preparing lime. It has the form of a high cylinder, with a hearth at the side, and at some distance above the base.

The combustible is placed on the hearth, and burns with an inverted or reflected flame. The lime is taken out at the bottom, while fresh additions of limestone are made at the top; and thus the oven is preserved constantly hot.

Limestone recently dug, and of course moist, calcines more easily than that which has become dry by exposure to the air; in the latter case it is found convenient even to moisten the stone, before putting it into the kiln.

Limestone loses about four ninths of its weight by burning, but is nearly of the same bulk.

Lime thus obtained is called quicklime. If it be wet with water, it instantly swells and cracks, becomes exceedingly hot, and at length falls into a white, soft, impalpable powder. This process is denominated the slacking of lime. The compound formed is called the hydrate of lime, and consists of about three parts of lime to one of water. When intended for mortar, it should immediately be incorporated with sand, and used without delay, before it imbibes carbonic acid anew from the atmosphere. Lime doubles its bulk by slacking.

### SECTION VIII. — Of Mortars and Cements.

In the construction of works in masonry, we generally employ some kind of cementitious matter for connecting the stones together, and rendering them firm and compact. When the works are to be exposed to the action of water immediately after being built, this cementitious matter must be of such a nature that it will harden under water. Hence it is, that we have occasion for two kinds of mortar, one that will set and harden under water, called by Smeaton a *water-mortar*, or cement; and *common* mortar for ordinary buildings.

*Common Mortar*, it is almost superfluous to say, is a preparation of lime and sand, mixed with water, which serves to unite the stones in the building of walls, &c., and on the proper or improper manner in which such mortar is prepared and used depends the durability and security of buildings; we shall, therefore, here introduce many particulars on this head, discovered by Smeaton, Dr. Higgins, &c., but which, not being generally known, have never been introduced into general practice.

Limestone, marble, chalk, or shells, may be used to burn for lime for common mortar, all these substances being composed chiefly of lime and carbonic acid; and if a piece of one of them be slowly burnt or calcined, so as to expel the whole, or nearly the whole, of its carbonic acid, it loses about forty-four per cent. of its weight; and when a small quantity of water is added to the calcined matter, it swells, gives out heat, and falls into a finely divided powder called *slacked lime*. The bulk of the powder is about double that of the limestone.

If this powder be rapidly formed into a stiff paste with water, it sets or solidifies as a hydrate of lime, and ultimately hardens by the absorption of carbonic acid from the air. This constitutes common building mortar. Hydrate of lime consists of one hundred parts of lime and thirty-one parts of water. Common limestone consists of carbonate of lime, with very little of any other substances; it produces a white lime, which slacks freely when well burnt; it dissolves in diluted muriatic acid, with only a small portion of residue, and never contains more than a trace of iron. It differs much in external characters, as chalk, marble, common compact limestone, &c.

These limestones do not form cements to set in water, without the addition of other kinds of cementing matter; hence they are usually employed only for common mortar. The hardest marble and the softest chalk make equally good lime when well burnt; but chalk-lime will slack when not perfectly burnt, and, therefore, has a sufficient quantity of fire; whereas stone-lime must have sufficient to make it slack. It was also observed by Dr. Higgins, that stone-lime does not reabsorb carbonic acid so rapidly as chalk-lime. Lime made from common limestone sustains very little injury from being kept after it has been formed into mortar, provided the air be effectually excluded; indeed, Alberti mentions an instance of some which had been covered up in a ditch for a very long time, and yet was found to be of an excellent quality.

Sand. To employ lime alone in the composition of mortar would render it expensive; besides it would be of inferior quality. The material commonly used to mix with lime is sand, and this sand should be of a hard nature, not very fine, but angular, and having considerable affinity for lime; also, the more irregular it is in size the better. It should be free from any mixture of soft or earthy matter, if it can be procured without. The reason is obvious; for mortar composed of soft sand cannot be harder than that sand. Sea-sand makes good mortar, particularly water-mortar. Very hard burnt brick, or tile, reduced to a coarse powder, also makes an excellent substance to mix with lime, for many purposes.

The best proportion of sand for common mortar is easily ascertained by trial; enough should be added to render the mortar rather short than tough under the trowel. The proportion varies from four parts of sand to one of lime, to one and one fourth parts of sand to one of lime, by measure; the proportion differing according to the coarseness of the sand, the nature of the limestone, and the precautions used in burning it; all set proportions being universally adhered to only by those who are utterly ignorant of the subject. In many situations, it is impossible to procure good sand except at an enormous expense.

Making Mortar. The instructions given by Dr. Higgins for making stucco mortar apply only when a very superior kind is wanted; but the same general principles ought to be followed even with the commonest kinds of mortar. We will therefore insert them in this place.

Of *sand*, the following kinds are to be preferred. First, *drift-sand*, or *pit-sand*, which consist chiefly of hard, quartzose, flat-faced grains, with sharp angles. Secondly, that which is the freest, or may be most easily freed by washing, from clay, salts, and calcareous, gypseous, or other grains less hard and durable than quartz. Thirdly, that which contains the smallest quantity of pyrites, or heavy metallic matter, inseparable by washing. And, fourthly, that which suffers the smallest diminution of its bulk by washing. Where a coarse and fine sand of this kind, and corresponding in the size of their grains with the coarse and fine sands hereafter described, cannot be easily procured, let such sand of the foregoing quality be chosen, as may be sorted and cleansed in the following manner.

Let the sand be sifted in streaming cold water, through a sieve which shall give passage to all such grains as do not exceed one sixteenth of an inch in diameter; and let the stream of water and the sifting be regulated so that all the sand which is much finer than the Lynn sand, commonly used in the London glasshouses, together with clay, and every other matter specifically lighter than sand, may be washed away with the stream; whilst the purer and coarser sand, which passes through the sieve, subsides in a convenient receptacle, and the coarse rubbish and rubble remain on the sieve, to be rejected.

Let the sand which thus subsides in the receptacle be washed in clean streaming water, through a fine sieve, so as to be further cleansed, and sorted into two parcels; a coarser, which will remain in the sieve, which is to give passage to such grains of sand only as are less than one thirtieth of an inch in diameter, and which is to be saved apart, under the name of *coarse sand;* and a finer, which will pass through the sieve and subside in the water, and which is to be saved apart, under the name of *fine sand.* Let the coarse and the fine sand be dried separately, either in the sun or on a clean plate, set on a convenient surface, in the manner of a sand heat.

Let *stone-lime* be chosen which heats the most in slacking, and slacks the quickest when duly watered; that which is the freshest made and closest kept; that which dissolves in distilled vinegar with the least effervescence, and leaves the smallest residue insoluble, and in the residue the smallest quantity of clay, gypsum, or iron. Let the lime chosen according to these rules be put in a brass-wired sieve, to the quantity of fourteen pounds. Let the sieve be finer than either of the foregoing; the finer the better it will be. Let the lime be slacked, by plunging it into a butt filled with soft water, and raising it out quickly, and suffering it to heat and fume, and, by repeating this plunging and raising alternately, and agitating the lime until it be made to pass through the sieve into the water; and let the part of the lime which does not easily pass through the sieve be rejected; and let fresh portions of the lime be thus used, until as many ounces of lime have passed through the sieve as there are quarts of water in the butt.

Let the water, thus impregnated, stand in the butt closely covered, until it becomes clear, and through wooden cocks, placed at different heights in the butt, let the clear liquor be drawn off, as fast and as low as the lime subsides, for use. This clear liquor is called *lime-water.* The freer the water is from saline matter, the better will be the cementing liquor made with it. Let fifty-six pounds of the aforesaid chosen lime be slacked, by gradually sprinkling the lime-water on it, and especially on the unslacked pieces, in a close clean place. Let the slacked part be immediately sifted through the last mentioned brass-wired sieve; and let the lime which passes be used instantly, or kept in air-tight vessels, and the part of the lime which does not pass through the sieve be rejected. This finer and richer part of the lime, which passes through the sieve, may be called *purified lime.*

Let bone-ash be prepared in the usual manner, by grinding the whitest burnt bones; but let it be sifted, so as to be much finer than the bone-ash commonly sold for making cupels.

The best materials for making cement being thus prepared, take fifty-six pounds of the coarse sand, and forty-two pounds of white sand; mix them on a large plank of hard wood, placed horizontally; then spread the sand so that it may stand to the height of six inches, with a flat surface on the plank; wet it with the lime-water, and let any superfluous quantity of the liquor, which the sand in the condition described cannot retain, flow away off the plank. To the wetted sand add fourteen pounds of the purified lime, in several successive portions, mixing and beating them up together, in the mean time, with the instruments generally used in making fine mortar; then add fourteen pounds of the bone-ash, in successive portions, mixing and beating all together.

The quicker and the more perfectly these materials are mixed and beaten together, and the sooner the cement thus formed is used, the better it will be. This may be called *coarse-grained cement*, which is to be applied in building, pointing, plastering, stuccoing, or other work, as mortar and stucco generally are; with this difference chiefly, that, as this cement is shorter than mortar, or common stucco, and dries sooner, it ought to be worked expeditiously, in all cases; and in stuccoing it ought to be laid on by sliding the trowel upwards on it. The materials used along with this cement, in building, or the place on which it is to be laid, in stuccoing, ought to be well wetted with the lime-water, in the instant of laying on the cement. The lime-water is also to be used when it is necessary to moisten the cement, or when a liquid is required to facilitate the floating of the cement.

When such cement is required to be of a still finer texture, take ninety-eight pounds of the fine sand, wet it with the lime-water, and mix it with the purified lime and the bone-ash, in the quantities and in the manner described; with this difference only, that fifteen pounds of lime, or thereabouts, are to be used instead of fourteen pounds, if the greater part of the sand be as fine as Lynn sand. This may be called *fine-grained cement.* It is used in giving the last coating, or the finish, to any work intended to imitate the finer-grained stones, or stucco. But it may be applied to all uses of the *coarse-grained cement*, and in the same manner.

When, for any of the foregoing purposes of pointing, building, &c., a cement is required much cheaper and coarser-grained than either of the foregoing, then much coarser clean sand than the foregoing coarse sand, or well washed fine rubble, is to be provided. Of this coarse sand, or rubble, take fifty-six pounds; and after mixing these, and wetting them with the cementing liquor, in the foregoing manner, add fourteen pounds, or somewhat less, of the purified lime, and then fourteen pounds, or somewhat less, of the bone-ash, mixing together in the manner already described. When the cement is required to be white, white sand, white lime, and the whitest bone-ash are to be chosen. Gray sand, and gray bone-ash, formed of half-burnt bones, are to be chosen to make cement gray; and any other color of the cement is obtained, either by choosing colored sand, or by the admixture of the necessary quantity of colored talc, in powder, or of colored, vitreous, or metallic powders, or other durable coloring ingredients commonly used in paint.

This cement, whether the coarse or fine-grained, is applicable in forming artificial stone, by making alternate layers of the cement and of flint, hard stone, or bricks, in moulds of the intended stone, and by exposing the masses so formed to the open air, to harden.

When such is required for water-fences, two thirds of the prescribed quantity of bone-ashes are to be omitted; and, in the place thereof, an equal measure of powdered terras is to be used; and if the sand employed be not of the coarsest sort, more terras must be added, so that the terras shall be one sixth part of the weight of the sand.

When such a cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush, flint-powder, or the powder of any quartzose or hard earthy substance, may be used in the place of sand, but in a quantity smaller in proportion as the flint or other powder is finer; so that the flint-powder, or other such powder, shall not be more than six times the weight of the lime, nor less than four times its weight. The greater the quantity of lime within these limits, the more will the cement be liable to crack by quick drying, and *vice versâ.*

Where the above-described sand cannot be conveniently procured, or where the sand cannot be conveniently washed and sorted, that which most resembles the mixture of coarse and fine sand above prescribed may be used, as directed, provided due attention be paid to the quantity of the lime, which is to be greater as the quality is finer, and *vice versâ.*

Where sand cannot be easily procured, any durable stony body, or baked earth, grossly powdered and sorted nearly to the sizes above prescribed for sand, may be used in the place of sand, measure for measure, but not weight for weight, unless such gross powder be specifically as heavy as sand.

Sand may be cleansed from every softer, lighter, and less durable matter, and from that part of the sand which is too fine, by various methods, preferable, in certain circumstances, to that which has been already described.

Water may be found naturally free from fixable gas, selenite, or clay; such water may, without any great inconvenience, be used in the place of the lime-water; and water approaching this state will not require so much lime as above prescribed to make the lime-water; and a lime-water sufficiently useful may be made by various methods of mixing lime and water, in the described proportions, or nearly so.

When stone-lime cannot be procured, chalk-lime, or shell-lime, which best resembles stone-lime in the foregoing characters of lime, may be used in the manner described, excepting that fourteen pounds and a half of chalk-lime will be required in the place of fourteen pounds of stone-lime. The proportion of lime, as prescribed above, may be increased without inconvenience, when the cement or stucco is to be applied where it is not liable to dry quickly; and, in the contrary case, this proportion may be diminished. The defect of lime, in quantity or quality, may be very advantageously supplied by causing a considerable quantity of lime-water to soak into the work, in successive portions, and at distant intervals of time; so that the calcareous matter of the lime-water, and the matter attracted from the open air, may fill and strengthen the work.

The powder of almost every well dried or burnt animal substance may be used instead of bone-ash; and several earthy powders, especially the micaceous and the metallic; and the elixated ashes of divers vegetables, whose earth will not burn to lime, as well as the ashes of mineral fuel, which are of the calcareous kind, but will not burn to lime, will answer the ends of bone-ash, in some degree. The quantity of bone-ash described may be lessened without injuring the cement; in those circumstances, especially, which admit the quantity of lime to be lessened, and in those wherein the cement is not liable to dry quickly. The art of remedying the defects of lime may be advantageously practised to supply the deficiency of bone-ash, especially in building and making artificial stone with this cement.

As the preceding method of making mortar differs, in many particulars, from the common process, it may be useful to inquire into the causes on which this difference is founded.

When the sand contains much clay, the workmen find that the best mortar they can make must contain about one half lime; and hence they lay it down as certain, that the best mortar is made by the composition of half sand and half lime.

But with sand requiring so great a proportion of lime as this, it will be impossible to make good cement; for it is universally allowed that the hardness of mortar depends on the crystallization of the lime round the other materials which are mixed with it, and thus uniting the whole mass into one solid substance. But if a portion of the materials used be clay, or any other friable substance, it must be evident, that, as these friable substances are not changed in one single particular by the process of being mixed up with lime and water, the mortar of which they form a proportion will consequently be more or less of a friable nature, in proportion to the quantity of friable substances used in the composition of the mortar. On the other hand, if mortar be composed of lime and good sand only, as the sand is a stony substance, and not in the least friable, and as the lime, by perfect crystallization, becomes likewise of a stony nature, it must follow, that a mass of mortar, composed of these two stony substances, will itself be a hard, solid, unfriable substance. This may account for one of the essential variations in the preceding method from that in common use, and point out the necessity of never using in the place of sand, which is a durable, stony body, the scrapings of roads, old mortar, and other rubbish from ancient buildings, which are frequently made use of, as all of them consist, more or less, of muddy, soft, and minutely divided particles. Another essential point is the nature and quality of lime. Now experience proves, that, when lime has been long kept in heaps or untight casks, it is reduced to the state of chalk, and becomes every day less capable of being made into good mortar; because, as the goodness or durability of the mortar depends on the crystallization of the lime, and as experiments have proved that lime, when reduced to this chalk-like state, is always incapable of perfect crystallization, it must follow that, as lime in this state never becomes crystallized, the mortar, of which it forms the most indispensable part, will necessarily be very imperfect; that is to say, it will never become a solid stony substance; a circumstance absolutely required in the formation of good durable mortar. These are the two principal ingredients in the formation of mortar; but, as water is also necessary, it may be useful to point out which is the fittest for this purpose; the best is rain-water, river-water the second, land-water next, and spring-water last. The ruins of the ancient Roman buildings are found to cohere so strongly, as to have caused an opinion that their constructors were acquainted with some kind of mortar which, in comparison with ours, might justly be called *cement;* and that to our ignorance of the materials they used is owing the great inferiority of modern buildings in their durability. But a proper attention to the above particulars would soon show, that the durability of the ancient edifices depended on the manner of preparing their mortar more than on the nature of the materials used. The following observation will, we think, prove this beyond a possibility of doubt. Lime which has been slacked and mixed with sand becomes hard and consistent when dry, by a process similar to that which produces *stalactites* in caverns. These are always formed by water dropping from the roof. But when the small drop of water comes to be exposed to the air, the calcareous matter contained in it begins to separate from the water, and to reassume its native form of limestone or marble.

When the calcareous matter is perfectly crystallized in this manner, it is, to all intents and purposes, limestone or marble of the same consistence as before. If lime in a caustic state be mixed with water, part of the lime will be dissolved, and will also begin to crystallize. The water which parted with the crystallized lime will then begin to act upon the remainder, which it could not dissolve before, and thus the process will continue, either till the lime be all reduced to an effete or crystalline state, or something hinders the action of water upon it. It is this crystallization which is observed by the workmen when a heap of lime is mixed with water, and left for some time to macerate. A hard crust is formed upon the surface, which is ignorantly called *frostling*, though it takes place in summer as well as in winter.

If, therefore, the hardness of the lime, or its becoming a cement, depends entirely on the formation of its crystals, it is evident that the perfection of the cement must depend on the perfection of the crystals, and the hardness of the matters which are entangled among them. The additional substances used in making of mortar, such as sand, brick-dust, or the like, serve only for a purpose similar to what is answered by sticks put into a vessel full of any saline solution : namely, to afford the crystals an opportunity of fastening themselves upon it. If, therefore, the matter interposed between the crystals of the lime is of a friable, brittle nature, such as brick-dust or chalk, the mortar will be of a weak and imperfect kind; but when the particles are hard, angular, and very difficult to be broken, such as those of river or pit-sand, the mortar turns out exceedingly good and strong.

That the crystallization may be the more perfect, a large quantity of water should be used, the ingredients be perfectly mixed together, and the drying be as slow as possible. An attention to these particulars, and to the quality of bricks and stones, would make the buildings of the moderns equally durable with those of the ancients. In the old Roman works, the great thickness of the walls necessarily required a vast time to dry. The middle of them was composed of pebbles, thrown in at random, and which evidently had thin mortar poured in among them. Thus a great quantity of the lime would be dissolved, and the crystallization performed in the most perfect manner. The indefatigable pains and perseverance, for which the Romans were so remarkable in all their undertakings, leave no room to doubt that they would take care to have the ingredients mixed together as well as possible. The consequence of all this is, that the buildings formed in this manner are all as firm as if cut out of a solid rock, the mortar being equally hard, if not more so than the stones themselves.

Water Mortars or Cements. The cementing materials are either found ready combined in certain kinds of stone, as in the case of Roman cement; or the effect is produced by mixture, as when we mix the lime of poor limestones with Dutch terras. The natural combination is, however, by far the best, and it is only in cases where the other can be obtained at a much less expense, that we advise it to be resorted to; but for such cases we propose to describe the best compositions now known.

*Roman Cement* is made from the kind of stones called *clay-balls*. The best stone contains about sixty per cent. of carbonate of lime, and eight or ten per cent. of protoxyd of iron, the rest being silex and alumine, nearly in equal parts. The inferior stones contain peroxyd of iron, and often soluble earthy and alkaline salts. Stone of the best kind is produced on the coast of the Isle of Sheppy, and from the alum-shale on the coast of Yorkshire, near Whitby. Stone of an inferior quality is procured near Harwich, and other places on the coast of England, and at Boulogne, in France. The stone is, after being broken to a proper size, slowly calcined in kilns or ovens, and then it is ground to a fine powder, of a light snuff color, when the stone is good, and of a deeper, approaching to a burnt umber-brown, when the quality is inferior. The powder should be kept perfectly dry, till it is used; and, in order to use it, mix it with not less than an equal portion, by measure, of dry, clean, and sharp river-sand; then add as much clear water as will form it into a stiff paste, but not more; and the whole that is so mixed must be used before it begins to set, which, with good cement, happens in about fifteen minutes from the time of adding water; but, in cements very fit for building, the setting may not be commenced in less than half or three quarters of an hour. When the setting begins, all the moisture on the surface disappears, and the cement feels dry and warm to the touch, and hardens; the hardening continues for some months, and is increased by frequently wetting the work, in cases where it has not to be exposed to water immediately on its being set. A coat of this cement is impervious to water, and it is therefore used for lining cisterns, tanks, reservoirs, &c. Roman cement may be used alone, but it does not become so hard and durable as when it has a proper quantity of good sand mixed with it. A mixture of Roman cement and common mortar should never be made, for their setting properties depend on different combinations, which interfere with each other when acting in the same mass; and the best mortar and best cement may be both rendered worthless by mixture. In using cement the more expeditious the workman is in his operations the better; and when once setting has commenced, the work should be no further disturbed. If the setting take place too rapidly for the nature of the work, let the cement, in powder, be spread out so as to expose a large surface to the air, in a dry place; in this manner the time of setting may be extended according to the time the powder is exposed; and though the quality of the cement is injured by the process, it is not so much destroyed as by working the cement after its being partially set.

*Puzzolana Mortar.* An excellent mortar for water-works is formed by combining the lime of poor limestones with the earth called puzzolana, which is procured in Italy. The limestones adapted for this purpose are the blue lias of Somersetshire, the clunch of Sussex, and the hard, gray chalk of Surrey. Smeaton used the lime of the lias, procured at Aberthaw, in Wales, for the Eddystone lighthouse, the proportions as follows: —

| | *Kind of Mortar.* | *Lime in Powder.* | *Puzzolana.* | *Clean Sand.* |
|---|---|---|---|---|
| No. 1. | Eddystone Mortar, | 2 bushels, | 2 bushels. | |
| No. 2. | Stone Mortar, | 2 " | 1 " | 1 bushel. |
| No. 3. | Do. (2d sort), | 2 " | 1 " | 2 " |
| No. 4. | Face Mortar, | 2 " | 1 " | 3 " |
| No. 5. | Do. (2d sort), | 2 " | ½ " | 3 " |
| No. 6. | Backing Mortar, | 2 " | ¼ " | 3 " |

Smeaton remarks, that mortar of the proportions of No. 1 will, in twelve months, acquire the hardness of Portland stone, when under water; and the others will in time acquire a stony hardness, if the materials have been thoroughly mixed and well beaten together. An article called British puzzolana has lately been manufactured, but it does not possess the same properties as the foreign kind, and, indeed, is rather a substitute for sand than for the true puzzolana.

*Terras Mortar* is also very good for water-works; it is composed of an earthy material called terras, found near Andernach, in the department of the Rhine and Moselle, which is mixed with any lime of a nature similar to the blue lias. Terras is much used by the Dutch, for their sea and canal works, and it has the singular property of forming stalactitical excrescences at the joints of the work. Smeaton employed it in the following proportions, according to the nature of the work, No. 1 being the best quality.

| *Kind of Mortar.* | *Lime in Powder.* | *Terras.* | *Clean Sand.* |
|---|---|---|---|
| No. 1. Terras Mortar, | 2 bushels, | 1 bushel. | |
| No. 2. Do. (2d kind), | 2 " | 1 " | 1 bushel. |
| No. 3. Do. (3d kind), | 2 " | 1 " | 2 " |
| No. 4. Do. (4th kind), | 2 " | 1 " | 3 " |
| No. 5. Backing Mortar, | 2 " | ½ " | 3 " |

The customary allowance of beating for terras mortar is a day's work of a man for every bushel of terras. When neither Roman cement, puzzolana, nor terras can be procured, except at great expense, then we may have recourse to calcined iron ore, scales from smiths' forges, calcined basalt, clay, and other substances containing a considerable proportion of protoxyd of iron. Lime may also be improved by peculiar treatment in burning, for it appears that even common chalk-lime acquires a setting property resembling that of the lias-lime, by being long exposed to a certain degree of heat. All limes fit for water-cements require to be ground to powder, and the finer the better. If these limes be slacked, the setting property is partially destroyed; and it is important that no more mortar should be made up at once than can be used within a few hours.

## SECTION IX. — Common Mortar and Cement.

These are the substances generally made use of for the uniting medium between bricks or stones, in forming them into buildings. Though many experiments have been made to ascertain the best materials for these compounds, and the mode of mixing them, and not without a degree of success, still much yet seems to remain to be discovered. A composition of lime, sand, and water, in consequence of the facility with which they pass from a soft state to a stony hardness, has, in common uses, superseded all other ingredients. But in order that the mortar should be of a good quality, great care and skill are requisite in the selection of the materials and the proportioning of them; and much depends on the degree of labor bestowed on the mixing and incorporation. The lime should be well burnt, and free from fixed air and carbonic acid. Hence, lime that has become effete, from exposure to the atmosphere, is impaired in its quality. The sand most proper for mortar is that which is wholly siliceous, and which is sharp, that is, not having its particles rounded by attrition. Fresh sand is to be preferred to that taken from the vicinity of the sea-shore, the salt of which is liable to deliquesce and weaken the strength of the mortar; it should be clean, rather coarse, and free from dirt and all perishable ingredients. The water should be pure, fresh, and, if possible, free from fixed air.

The proportions of lime and sand to each other are varied in different places; the amount of sand, however, always exceeds that of lime. The more sand that can be incorporated with the lime, the better, provided the necessary degree of plasticity is preserved; for the mortar becomes stronger, and it also sets, or consolidates more quickly, when the lime and water are less in quantity and more subdivided. From two to four parts of sand are commonly used to one of lime, according to the quality of the lime and the labor bestowed upon it. The more pure the lime is, and the more thoroughly it is beaten or worked over, the more sand it will take up, and the more firm and durable does it become.

## SECTION X.

The ancient masons were so very scrupulous in the process of mixing their mortar, that it is said the Greeks kept ten men constantly employed, for a long space of time, to each basin; this rendered their mortar of such prodigious hardness, that, Vetruvius tells us, the pieces of plaster falling off from old walls served to make tables.

It was a maxim among the old masons to their laborers, that they should dilute the mortar with the sweat of their brows; that is, labor a long time, instead of drowning it with water, to have it done the sooner.

The weakness of modern mortar compared to the ancient is a common subject of regret; and many ingenious men take it for granted, that the process used by the Roman architects in preparing their mortar is one of those arts which are now lost, and have employed themselves in making experiments for its recovery.

But the characteristic of all modern artists, builders among the rest, seems to be, to spare their time and labor as much as possible, and to increase the quantity of the article they produce, without much regard to goodness; and perhaps there is no manufacture in which it is so remarkably exemplified as in the preparation of common mortar.

## SECTION XI.

Mr. Doffie gives the following method of making mortar impenetrable to moisture, acquiring great hardness, and exceedingly durable, which was discovered by a gentleman of Neufchatel. Take of unslacked lime and of fine sand, in the proportion of one part of lime to three of sand, as much as a laborer can well manage at once; and then, adding water gradually, mix the whole well together with a trowel, till it be rendered to the consistency of mortar. Apply it immediately, while it is hot, to the purpose either of mortar as a cement to brick or stone, or of plaster to the surface of any building. It will then ferment for some days, in drier places, and afterwards gradually concrete or set, and become hard; but in a moist place it will continue soft for three weeks or more; though it will at length obtain a firm consistence, even if water have such access to it as to keep the surface wet the whole time. After this it will acquire a stone-like hardness, and resist all moisture. The perfection of this mortar depends on the ingredients being thoroughly blended together; and the mixture being applied immediately after to the place where it is wanted. The lime for this mortar must be made of hard limestone, shells, or marl; and the stronger it is, the better the mortar will be. When a very great hardness and firmness are requisite in this mortar, the using of skimmed milk instead of water, either wholly or in part, will produce the desired effect.

## SECTION XII. — Monsieur Loriat's Mortar.

*Monsieur Loriat's Mortar*, the method of making which was announced by order of his Majesty, at Paris, in 1774, is made in the following manner: — Take one part of brick dust, finely sifted, two parts of fine river-sand, screened, and as much old slacked lime as may be sufficient to form mortar with water, in the usual method, but so wet as to serve for the slacking of as much powdered quicklime as amounts to one fourth of the whole quantity of brick-dust and sand. When the materials are well mixed, employ the composition quickly, as the least delay may render the application imperfect, or impossible. Another method of making this compound is, to make a mixture of the dry materials; that is, of the sand, brick-dust, and powdered quicklime, in the prescribed proportion; which mixture may be put into sacks, each containing a quantity sufficient for one or two troughs of mortar. The above-mentioned old slacked lime and water being prepared apart, the mixture is to be made in the manner of plaster, at the instant when it is wanted, and is to be well chafed with the trowel.

## SECTION XIII.

Dr. Higgins has made a variety of experiments, in consequence of the modern discoveries relating to fixed air, for the purpose of improving mortar used in buildings. According to this author, the perfection of lime, prepared for the purpose of making mortar, consists chiefly in its being totally deprived of its fixed air. And as lime very quickly imbibes fixed air, when exposed to the atmosphere, it should be applied to use as soon as possible after it is prepared.

From the experiments of the same author, made with a view to ascertain the best relative proportions of lime, sand, and water, in the making of mortar, it appeared that those specimens were the best which contained one part of lime in seven of sand; for those which contained less lime, and were too short while fresh, were more easily cut and broken, and were pervious to water; and those which contained more lime, although they were closer in grain, did not harden so soon, or to so great a degree, even when they escaped cracking by lying in the shade to dry slowly.

Dr. Higgins has also shown, that though the setting of mortar, as it is called, is chiefly owing to its drying, yet its induration, or its acquiring a stony hardness, is not caused by its drying, as has been supposed, but depends principally on its acquiring carbonic acid, or fixed air from the atmosphere. In order to the greatest induration of mortar, therefore, it must be suffered to dry gently, and set; the drying must be effected by temperate air, and not accelerated by the heat of the sun, or fire. It must not be wet soon after it sets; and afterwards, it ought to be protected from wet as much as possible, until it is completely indurated. The same author describes a cement, or stucco, of his own invention, for incrustations external and internal, of very great hardness, for which he obtained letters patent. As for the materials of which it is made, drift sand, or quarry sand, consisting chiefly of hard, quartzose, flat-faced grains, with sharp angles, free from clay, salts, &c., is to be preferred. The sand is to be sifted in streaming clear water, through a sieve which shall give passage to all such grains as do not exceed one sixteenth of an inch in diameter; and the stream of water, and sifting, are to be so regulated, that all the finer sand, together with clay and other matter lighter than sand, may be washed away with the stream. While the purer and coarser sand, which passes through the sieve, subsides in a convenient receptacle, the coarse rubbish in the sieve is to be rejected. The subsiding sand is then washed in clean streaming water, through a finer sieve, so as to farther cleanse it, and sorted into two parcels, — a coarser, which will remain in the sieve, which is to give passage only to such grains as are less than one thirteenth of an inch in diameter, and which is to be kept apart under the name of coarse sand; and a finer which will pass through the sieve, and subside in the water, and which is to be saved apart under the name of fine sand. These are to be dried separately, either in the sun or on a clean iron plate, set on a convenient surface, in the manner of a sand heat. The lime to be chosen should be stone-lime, which heats the most in slacking, and slacks the quickest when duly watered; which is the freshest made, and most closely kept. Let this lime be put into a brass-wired, fine sieve, to the quantity of fourteen pounds. Let the lime be slacked by plunging it in a butt, filled with soft water, and raising it out quickly, and suffering it to heat and fume, and by repeating this plunging and raising alternately, and agitating the lime, until it be made to pass through the sieve. Reject the part of the lime that does not easily pass through the sieve, and use fresh portions of lime till as many ounces have passed through the sieve as there are quarts of water in the butt. Let the water thus impregnated stand in the butt, close covered, until it becomes clear; and through wooden cocks, placed at different heights in the butt, draw off the clear liquor, as fast and as low as the lime subsides, for use. This clear liquor is called the cementing liquor.

Let fifty-six pounds of the aforesaid chosen lime be slacked, by gradually sprinkling on it the cementing liquor, in a close, clean place. Let the slacked part be immediately sifted through the fine brass-wired sieve. Let the lime which passes be used instantly, or kept in air-tight vessels, and let the part of the lime which does not pass through the sieve be rejected; the other part is called purified lime.

Let bone-ashes be prepared in the usual manner, by grinding the whitest burnt bones; but they should be finely sifted.

Having thus prepared the materials, take fifty-six pounds of the coarse sand, and forty-two pounds of the fine sand; mix them on a large plank of hard wood, placed horizontally. Then spread the sand so that it may stand at the height of six inches, with a flat surface on the plank; wet it with the cementing liquor; to the wetted sand add fourteen pounds of the purified lime, in several successive portions, mixing and beating them together; then add fourteen pounds of the bone-ashes in successive portions, mixing and beating them all together. This Dr. Higgins calls the water cement, coarse-grained, which is to be applied in building, pointing, plastering, stuccoing, &c. Observing to work it expeditiously in all cases, and in stuccoing to lay it on by sliding the trowel upwards upon it; to well wet the materials used with it, or the ground on which it is laid, with the cementing liquor, at the time of laying it on; and to use the cementing liquor for moistening the cement and facilitating the floating of it.

A cement of a finer texture may be made, by using ninety pounds of the fine sand, and fifteen pounds of lime, with bone-ashes and cementing liquor. This is called water cement, fine-grained, and is used in giving the last coating or finish to any work intended to imitate the finer-grained stones or stucco.

For a cheaper or coarser cement, take of coarse sand fifty-six pounds, of the foregoing coarse sand twenty-eight pounds, and of the finer sand fourteen pounds; and after mixing and wetting these with the cementing liquor, add fourteen pounds of the purified lime, and then as much bone-ashes, mixing them together. The water cement above described is applicable to forming artificial stone, by making alternate layers of the cement and of flint, hard stone, or brick, in moulds of the figure of the intended stone, and by exposing the masses so formed to the open air to harden. When the cement is required for water fences, two thirds of the bone-ashes are to be omitted, and in their stead an equal measure of powdered terras (see *Terras*) is to be used. When the cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush, flint powder, or the powder of any quartzose, or hard, earthy substance, may be used in the place of sand, so that the powder shall not be more than six times the weight of the lime, nor less than four times its weight. For inside work the admixture of hair with the cement is useful.

When a fragment of a worked stone is, by accident or otherwise, broken off, it may be united with a firmness sufficient to resist a considerable degree of force by a cement made of five parts of *gum shellac*, and one part of *Burgundy pitch*, incorporated together in an iron vessel, over a slow fire. The cement, while hot, should be applied to the stone, raised also to a moderate degree of heat. In order that the cement should not cool too rapidly, a piece of iron should be heated, and laid on the stone, and the whole suffered to cool gradually together. The cement may be made to assume the color of the stone to be united, by mixing with it a portion of the stone itself, reduced to a fine powder. Stones thus united may afterwards be smoothed by gentle hammering, while the fracture is not perceptible, except by very close examination.

## SECTION XIV.

ALTHOUGH a well made mortar, composed merely of sand and lime, allowed to dry, becomes impervious to water, so as to serve for the lining of reservoirs and aqueducts; yet if the circumstances of the building are such as to render it impracticable to keep out the water, whether fresh or salt, a sufficient length of time, the use of common mortar must be abandoned.

Among the nations of antiquity, the Romans appear to have been the only people who have practised building in water, and especially in the sea, to any extent. The bays of Baiæ, of Pozzuolo, and of Cumæ, from their coolness and salubrity of situation, were the fashionable resorts of the wealthier Romans, during the summer months; who not only erected their villas and baths as near the shore as possible, but constructed moles and formed small islands in the more sheltered parts of these bays; on which, for the sake of the grateful coolness, they built their summer-houses and pavilions. They were enabled to build thus securely by the discovery, at the town of Puteoli, of an earthy substance, which was called *pulvis puteolanus*, Puteolan powder, or, as it is now called, puzzolana (which see). The only preparation which this substance undergoes is that of pounding and sifting, by which it is reduced to a coarse powder; in this state, being thoroughly beaten up with lime, either with or without sand, it forms a mass of remarkable tenacity, which speedily sets, under water, and becomes, at least, as hard as good freestone.

Limes which contain a portion of clay, or argillaceous matter, have also the property of forming a mortar, which hardens under water. A composition formed of two bushels of clayey lime, one bushel of puzzolana, and three of clean sand, the whole being well beaten together, make a good water cement.

The terras which is so much used in Holland is a preparation of a species of basalt (which see), by calcination. It possesses the property, when mixed with lime, of forming a water cement, not inferior to puzzolana. Perhaps common greenstone and other substances may be found to answer the same purposes.

The materials of terras mortar, generally used in the construction of the best water work, are one measure of quicklime, or two measures of slacked lime, in the dry powder, mixed with one measure of terras, well beaten together to the consistency of paste, using as little water as possible.

Another kind almost equally good, and considerably cheaper, is made of two measures of slacked lime, one of terras, and three of coarse sand; it requires to be beaten longer than the foregoing, and produces three measures and a half of excellent mortar. When the building is constructed of rough, irregular stones, where cavities and large joints are to be filled up with cement, the pebble or coarse-sand mortar may be most advantageously applied; this was a favorite mode of constructing among the Romans, and has been much used since. Pebble mortar will be found of a sufficient compactness, if composed of two measures of slacked, argillaceous lime, half a measure of terras, or puzzolana, and one measure of coarse sand, one of fine sand, and four of small pebbles, screened and washed. It is only under water that terras mortar sets well.

The scales produced by hammering red-hot iron, which may be procured at the forges and blacksmiths' shops, have been long known as an excellent material in water cements. The scales being pulverized and sifted, and incorporated with lime, are found to produce a cement equally powerful with puzzolana mortar, if employed in the same quantity.

Fresh-made mortar, if kept under ground, in considerable masses, may be preserved for a great length of time, and the older it is before it is used, the better it has been thought to be.

Pliny informs us that the ancient Roman laws prohibited builders from using mortar that was less than three years old, and a similar law prevails in Vienna.

## SECTION XV. — Stucco.

This is a composition of white marble, pulverized and mixed with plaster, or lime, the whole sifted and wrought up with water, to be used like common plaster.

Of this are made statues, busts, basso-relievos, and other ornaments of architecture.

A stucco, for walls, &c., may be formed of the grout, or putty, made of good stone-lime, or the lime of cockle-shells, which is better, properly tempered and sufficiently beat, mixed with sharp grit sand, in a proportion which depends on the strength of the lime. Drift-sand is best for this purpose, and it will derive advantage from being dried on an iron plate or kiln, so as not to burn ; thus the mortar would be discolored. When this is properly compounded, it should be put in small parcels against walls, or otherwise, to mellow, as the workmen term it ; reduced again to soft putty, or paste, and spread thin on the walls without any under coat, and well trowelled. A succeeding coat should be laid on before the first is quite dry, which will prevent points of brick-work appearing through it. Much depends on the workman giving sufficient labor, and trowelling it down. If this stucco, when dry, be laid over with boiling linseed oil, it will last a long time, and not be liable, when once hardened, to the accidents to which common stucco is liable.

## SECTION XVI.

*Adam's Oil Cement*, or *Stucco*, is prepared in the following manner. For the first coat take twenty-one pounds of fine whiting, or oyster-shells, or any other sea-shells calcined, or plaster of Paris, or any calcareous material calcined and pounded, or any absorbent materials whatever, proper for the purpose; add white or red lead at pleasure, deducting from the other absorbent materials in proportion for the white or red lead added; to which put four quarts, beer measure, of oil, and mix them together with a grinding mill or any levigating machine; and afterwards mix and beat up the same well with twenty-eight quarts, beer measure, of any sand or gravel, or of both, mixed and sifted, or of marble or stone pounded, or of brick-dust, or of any kind of metallic or mineral powders, or of any solid material whatever, fit for the purpose.

For the second coat take sixteen pounds and a half of superfine whiting, or oyster-shells, or any sea-shells calcined, &c., as for the first coat; add sixteen pounds and a half of white or red lead, to which put six quarts and a half of oil, wine measure, and mix them together as before. Afterwards mix and beat up the same well with thirty quarts, wine measure, of fine sand or gravel sifted, or stone or marble pounded, or pyrites, or any kind of metallic or mineral powder, &c. This composition requires a greater proportion of sand, gravel, or other solids, according to the nature of the work, or the uses to which it is to be applied. If it be required to have the composition colored, add to the above ingredients such a portion of painters' colors as will be necessary to give the tint or color required. In making the composition, the best linseed, or hemp-seed, or other oils, proper for the purpose, are to be used, boiled or raw, with drying ingredients, as the nature of the work, the season, or the climate requires; and in some cases beeswax may be substituted in place of oil. All the absorbent and solid materials must be kiln-dried. If the composition is not to be any other color than white, the lead may be omitted, by taking the full proportion of the other absorbents; and also white or red lead may be substituted alone, instead of any absorbent material.

The first coat of this composition is to be laid on with a trowel, and floated to an even surface, with a rule or handle float. The second coat, after it is laid on with a trowel, when the other is nearly dry, should be worked down and smoothed, with floats edged with horn, or any hard, smooth substance, that does not stain. It may be proper, previously to laying on the composition, to moisten the surface on which it is to be laid, by a brush, with the same kind of oil or ingredients which pass through the levigating machine, reduced to a more liquid state, in order to make the composition adhere the better. This composition admits of being modelled, or cast in moulds, in the same manner as plasterers or statuaries model or cast their stucco-work. It also admits of being painted upon, and adorned with landscape, or ornamental, or figure painting, as well as plain painting.

## SECTION XVII. — Scagliola.

This composition has, of late years, begun to be much employed in the interiors of mansions, and may be applied not only to columns, their capitals and bases, but also to the panelling of walls, &c.

The formation of columns, &c., in scagliola, is a distinct branch of plastering. It was first invented in Italy, thence carried to France, and afterwards to England. The credit of its introduction into England belongs to Henry Holland, Esq., architect.

He procured artists from Paris to perform works with this composition at Carlton Palace, some of whom, finding a considerable demand for their productions, remained in England, from whom British workmen learnt the art, and have since brought it to the greatest perfection.

Scagliola is a composition of plaster of Paris and earthy colors, or any colors which will withstand the action of an alkali. In its manufacture, the ground or predominating color is first mixed to the desired tint, and the other colors intended to be introduced must be mixed separately, with a portion of clear size, and a little spirits of turpentine, to facilitate the drying.

If, in the marble intended to be imitated, the colors blend gradually into each other, as in Sienna and the others generally executed, the imitation must be formed while the colors are in a soft state, by putting the ground mixture into a large trough, and adding the different colors in a proportion and a taste which can alone be acquired by experience.

If, on the contrary, the distinction between the colors is strongly marked, the secondary colors must be allowed to set nearly hard, broken into small pieces, and added to the ground mixture, which must be kept in the trough in a soft state, as before mentioned.

## SECTION XVIII. — Manner of forming Columns or Pilasters in Scagliola.

When the architect has furnished the drawing exhibiting the diameter of the shaft, a cradle is made of wood about two and one half inches less in diameter than the projected column. The circumference of this cradle being lathed with double laths, as in common plastering, must be covered with a pricking-up coat of plaster, gauged with very thin size, in order to harden it.

The pricking-up coat, after being completely set, must be well soaked with water. The composition must be then taken from the trough, flattened into cakes about eight inches square, applied to the column, and well beat on with a wooden beater and small gauging-trowel. In this state it must remain until perfectly dry, when the protuberances may be taken off, with a plane. The column must then be put in the lathe and turned to the size required. This operation being finished, it will have a porous appearance, which must be obviated by the application of a thick wash, and scraping it with steel scrapers until it assumes the surface of real marble, when it will be fit for polishing, which must be effected by first using pumice-stone, at the same time cleansing it with a wet sponge, and afterwards with Tripoli powder and charcoal. After going over the whole with a piece of white glove-leather, dipped in a mixture of Tripoli powder and oil of olives, the process must be finished by the application of pure oil.

White scagliola is simply a mixture of plaster of Paris and mineral green, the manner of using it being the same as above described.

## SECTION XIX. — Modelling for Stucco or Plaster of Paris.

The whole of the ornaments cast in plaster of Paris are previously modelled in clay, which method has of late years almost entirely supplanted the process of working the ornaments in their places by hand.

Large works, such as angle-pieces and foliage for ceilings, require more judgment than enriched mouldings, such as ogees or ovelos, sthe eye of the modeller in the former case being his only guide, whereas, in the mouldings, the compasses are found of essential service. For example, in the moulding of an ogee, only one of the divisions is required to be modelled in clay, which may be effected by procuring a templet exactly corresponding with the profile of the moulding, and running a small portion of the moulding out with it in clay, in a small case of wood adapted to the purpose. The design of the ornament is then marked on the clay, and moulded to its peculiar form by the use of tools made of ebony and box, and finely polished with brass tools. When finished in the modelling, it is moulded in wax, and a sufficient number cast and fixed together to a length varying from eight inches to one foot, and afterwards cleaned up and corrected with steel and brass tools. This piece of ornament, after being properly corrected, is called the original, as an unlimited number of moulds may be taken from it. In moulding angle-pieces it is necessary to run out a sufficient quantity of the plain moulding in putty and plaster to the exact form of the angle. The embellishments are then modelled on the mouldings, and also moulded there-on, the mouldings forming a ground for the ornaments, so that, after being cast, they will exactly fit the mouldings when fixed in their proper situations on the ceiling.

## SECTION XX. — Moulding of Ornaments.

There are two methods of moulding practised by plasterers, namely, moulding in wax and moulding in plaster; the former is applied to all kinds of cornice enrichments, as friezes, soffits, ogees, ovolos, &c., and also to centre-flowers and angle-pieces; the latter is generally employed for works of large dimension, which, from the manner in which they are under cut, are not easily cast in wax moulds, as coats of arms, trophies, and plain capitals attached to trusses; it may also be applied to works in Roman cement, such as balustrades, heads, &c. In moulding in wax, the clay model must, in the first place, be well oiled with sweet oil, and a fence of clay put round it, to prevent the liquid wax from escaping, after which a sufficient quantity of wax and rosin must be dissolved together, which, when lukewarm, must be poured over the model, until it is completely covered. When the wax is sufficiently set, the whole must be immersed in water, which will cause it to leave more readily; after which, the clay being all washed out of the mould, it will be fit for casting in.

This method will be found sufficient where a face mould only is required, but when what is termed a back-and-front is wanted, as is the case in all leaves for centre-flowers, it is requisite to cut the front plaster-cast back, so that the ruffling will show distinctly, and afterwards to soak it in water. The leaf must then be backed up all round, within one sixteenth of an inch of the edge, with a substance of clay, an inch wide, in which rivets must be inserted. The leaf being freed from all particles of water which may remain on the surface, the clay must be well oiled. A fence of clay is then put round the whole, and the wax poured on, which, after remaining until quite hard, must be turned upside down, and the clay all removed from it, when the wax must be oiled or the whole brushed over with a little liquid clay. Another quantity of wax must be prepared, and, when almost cold, poured over the first, which will form the back mould; a fence of clay being provided, is put round to prevent the wax from escaping. When this mass is sufficiently set, the two parts may be disunited, and the plaster-leaf removed, thus forming two moulds, the one for casting the back, and the other the front of the leaf. This manner of moulding is also used for all kinds of foliages which need much relief.

## SECTION XXI. — Moulding in Plaster.

In moulding in plaster, the same as in wax, the clay model must be oiled with sweet oil, but the plaster must be laid (not too soft) by one piece at a time, forming the joints, and fitting them to each other, in such situations as the skill of the workman may suggest. After having completely covered the model with pieces, the whole must be removed, and, when perfectly dry, soaked in boiled linseed oil. The various parts of the mould, being well saturated with oil and quite dry, are fit for use, and may be oiled, ready for casting, with sweet oil, in the same manner as wax moulds.

*Casting in Plaster.* The moulds being prepared and properly cleansed, are oiled in the way above mentioned. A sufficient quantity of plaster of Paris, being mixed with water to a semi-fluid state, is well dubbed into the mould with a small brush, which, after remaining a short time, is floated off flush with the rim of the mould. The plaster being set, the impression is taken from the mould by means of pressing the wax gently with the hands all round, the heat of the plaster causing the mould to yield. The ornaments, after being taken from the mould, are cleaned up and cut with a trimming-knife to the proper joints, ready for the workman to fix in the places intended for their reception.

Friezes and basso-relievos should always be cut with a half-inch ground at their backs, which serves to strengthen and secure their proportions.

## SECTION XXII. — Fixing Ornaments.

When the enrichments about to be fixed are small in size, they may be fixed in the grooves or indents prepared for them with putty well gauged with plaster; but when the ornaments are of a weighty description, it becomes necessary to use fine stuff, and to cut away the plain surface of the work as far as the lathing. The place so cut away is then filled with gauged fine stuff, and the cast, being well scratched on the back in the form of a dovetail, must also have a portion of fine stuff laid on it when it is placed in its proper position, and pressed to the work, so that they may both incorporate. When the ornaments are extremely heavy, such as coats of arms and shields, in addition to the above mode, it is indispensably necessary to have recourse to large screws, which must pass through the cast work into the timber.

## SECTION XXIII. — Stucco Cornices.

Previous to the operation of forming the cornice, it should be the practice of the plasterer to examine the drawings, before the preparation is made for the pricking-up coat. When the projection does not exceed seven or eight inches, it is the practice, in filling in or blocking with coarse stuff, as common plastering mortar, to fill within one half or three quarters of an inch of the mould, and leave it as rough as possible for the putty to adhere to; but in case the cornice should project eight inches or over, it is best in most cases to bracket the angle of the ceiling. First fit a piece of pasteboard so as to conform to all the members of a section of the drawing, on the outside of the projections. The pasteboard may be pasted on to a thin plate of metal, of iron, copper, or steel, and by the means of files, &c., is fitted to the details of the mouldings cut out from the pasteboard. A piece of wood is fixed to the metallic mould about half an inch thick, so bevelled as not to clog in the moulding of the cornice, leaving the edge of the mould or metallic part to project about one half or one quarter of an inch from the wood backing. On the top and bottom part of the mould are attached two slides of wood, to keep the mould in a proper position on the screeds, and at a right angle with the wall; and sometimes a mould is made for the using of coarse stuff, which is about one eighth of an inch smaller in all of its members than the aforementioned mould. Bracketing is formed of inch-boards, so as to fall three quarters or one inch within the general projections of the aforesaid mould, and fastened up about one foot apart, and properly lathed, and covered with a coat of coarse stuff. The cutting of moulds being completed, the ceiling and walls floated and levelled, the projection of the cornice must be lined on the ceiling, and also its encroachment on the wall. At each line of projection, narrow screeds must be made, with a very thin coat of strong gauged fine stuff, and perfectly smoothed with the floating-rule. In the making of these screeds, much pains must be taken, as the correctness of the cornice depends upon the precaution used in their formation.

The running rules properly adjusted on a straight line, wooden strips about three inches wide and one half an inch thick nailed upon the protruding line on the wall, which has been done round the room for the purpose of directing the mould in forming the cornice,— the aforesaid preliminaries being attended to, it is fitted for running.

*Running the Cornice.* Two workmen and a boy are required, one to lay on the stuff, and the other to work the mould. The hawk-boy commences gauging the coarse stuff, which at first must be gauged; one of the workmen takes a portion of it on his hawk, and plasters a part of it on the place where the cornice is to be; the other workman begins, by moving the mould backward and forward, holding it firmly to the ceiling and wall, thus removing the superfluous stuff; this operation is continued until the cornice is as perfectly formed as can be with the coarse stuff. The putty and plaster is then gauged, and the same process pursued as in the coarse stuff, using the fine mould, adding gauged stuff until the exact contour of the cornice is formed.

When the cornice is very large, it may be best to run it by using two small moulds; one below, forming the plainer face and bed mouldings, and the other part forming the crown mouldings, &c.

The mitres internal and external, as well as breaks or small returns, are formed afterwards by hand, with small tools for the purpose.

### SECTION XXIV. — Circular and Elliptical Cornices or Mouldings.

This kind of cornice requires much more labor than straight ones, but the principal operation is the same, except that when they are circular they must be run from a centre, by means of what is called a gig-stick, to which the mould is attached; a hole being bored in it exactly to the radius, which fits to a pin placed exactly in the centre of the circular moulding. When the mouldings are to describe an ellipsis, the most correct method is to run them from a trammel, such as is used by carpenters.

### SECTION XXV. — External Compositions.

Within the last fifty years, great improvements have been made in the art of plastering by the invention of various compositions for the covering of the exteriors of buildings, such as Roman cement, terra cotta, mastic, and Bailey's composition.

These compositions are susceptible of being applied both to the finishing a plain surface to be jointed to imitate stone; and in the formation of ornaments of every description. On account of their cheapness, they have given rise to design and much architectural display, which heretofore was not thought of.

The careful study of the antique examples of architecture, both in Greece and ancient Rome, has also acted as a powerful stimulus to the promotion of the art of design, as well as ornamental plastering; more particularly in the getting up of Greek and Roman capitals, the former of which were, until within the last few years, scarcely known in Europe; and the latter have been most essentially improved by reference to the casts procured from the original, now extant.

The invention of composition has, no doubt, been facilitated by the scarcity of good stone in the south part of Great Britian. Other parts and other countries availing themselves of these improvements, have, in many instances, been led to farther study in the arts, and it operates as a stimulus to the taste for ornamental decorations and is of great utility to the public interests of this country, although probably no nation in the world possesses a greater variety of useful building materials than the United States of America.

*Roman Cement* or *Compo* was first introduced to public notice by the late James Wyatt, Esq. It was originally known as Parker's patent cement, but there is a much superior article prepared from the stone discovered by William Atkinson, Esq., on the estate of the Earl of Mulgrave, known by the name of Atkinson's cement. At the first, it costs a little more than the Roman cement, but it will bear a great deal more sand than the former, is of a more delicate stone color, and for situations constantly exposed to the action of water it is not surpassed by any cement now in existence.

*Roman Cement* is prepared from the kind of stone called clay-balls, or septaria, by being, after the manner of manufacturing plaster, first broken into pieces of a convenient size, slowly calcined in kilns or ovens, and afterwards ground to a fine powder, and put into proper casks. Two parts of composition, with three parts of clean grit sand, will form a very durable substitute for stone. In selecting the sand, great care must be taken to procure it possessing qualities of a sharp and binding nature, free from clay or mud. If it cannot be had free from these, it must be washed perfectly clean in fresh water.

After the walls intended to be covered have been well soaked with water, the cement must be prepared by the hawk-boy on a board made for the purpose, adding as much water as brings it to the consistency of paste. No more must be mixed than can be used in ten minutes. It must be laid on with the greatest expedition, in a coat of three fourths of an inch thick. After being well floated by means of the floating-rule, the hand-float must be incessantly used to bring it to a firm and solid surface before it sets, which takes place within fifteen minutes if the cement be good.

After the work has been drawn and jointed to imitate well-bonded masonry, it may be colored with a wash composed of five ounces of copperas to every gallon of water, mixed with a sufficient quantity of fresh lime and cement, adding the colors necessary to produce an exact imitation of any particular stone which may be required. When this mode of coloring is executed with judgment, and finished with taste, so as to produce a picturesque effect, by touching the divisions with rich tints of ochre, umber, &c., it is with difficulty distinguished from real stone. It has been attempted, and in some cases very successfully, to produce ancient Gothic ruins in cement, and although, to consummate the deception, great skill and judgment are required, yet we have no doubt that, by paying proper attention to the style of architecture, as well as the manner of coloring, imitations of this kind might be carried to great perfection.

*Terra Cotta* is an excellent as well as durable composition, made use of at the present day very advantageously for all kinds of exterior decorations. It is a composition of pipe-clay, stone bottles, glass, and flint, well pounded together, and sifted through a very fine sieve, a small portion of silver sand being afterwards added. The above ingredients must first be well mixed in a dry state, and then water added to reduce them to the pliability of moulder's clay. The mixture thus formed, having remained in this state for two or three days, must be beat or tempered in a similar manner to moulding clay, after which it is fit for use.

When applied to capitals, the bell or cover must be prepared not more than two and a half inches thick, the stuff of which it is composed being of a coarser nature than that used for its embellishments. After the ornaments, as the leaves, volutes, &c., have been modelled, they must be moulded in plaster, and squeezes of artificial stone taken from the moulds, well cleaned up with appropriate tools, and fixed to the bell. It is necessary, when the ornaments are fitted, to bore two or three holes, three fourths of an inch in diameter, on those parts of the bell where the enrichments are to be placed, in order to let the damp air escape in the process of burning.

To fix the ornaments, procure some of the dry composition, and let it remain in water about one day, then take out the portion that remains at the bottom, which, being well chafed on a hawk, composes the stuff for fixing.

After the bell and the back of the enrichments have been well wrought, a little soft stuff is rubbed on each, and the ornaments attached to the bell in the usual way.

The capital being then in a fit state for drying, must be left in the open air for that purpose, and, when thoroughly dried, placed in the kiln, which is composed of the same materials as a common oven, but of a somewhat different construction, as the flue must extend entirely over the covered ceiling of the kiln, and be perfectly clear of the ornament.

In the burning of terra cotta, it is necessary to commence with a very slow fire, gradually increasing it for the first week, after which a brisk fire must be kept up for three days and nights without intermission. The front of the kiln must then be closed with an iron plate, to prevent the ingress of the atmospheric air. Having remained three days in this situation, it is considered sufficiently burnt, and the kiln must be gradually opened, as the sudden admission of the air will cause the ornaments to crack or splinter.

*Method of moulding Terra Cotta.* The models being executed in clay, as is usual in moulding plaster ornaments, they must be moulded in the same manner as figures and busts, with this difference, that the clay must not be oiled, nor the joints of the plaster-pieces which compose the mould. Instead of oiling the model, it is washed with pure water, when the moulder may commence his operations. The various joints of the plaster-pieces in the mould must be touched with a small brush containing a little liquid clay (instead of oil, which is the general method), and great care taken in the formation of the different joints, as the pieces cannot be taken from the model to be cut and fitted, but must all be brought to their proper shapes while they remain on it. When the sufficient number of pieces are made, so as to completely envelope the model, a case of plaster must be put over the whole. In taking the form of the model, it is requisite to soak the whole in water, in order that they may leave the more readily, which being done, the mould must be well washed and put into the case and gradually dried in the air, when it will be fit for use without the process of seasoning in oil, as is customary in casting in plaster from a plaster mould.

*Manner of procuring Impressions from the Mould in Terra Cotta* (sometimes called *Squeezing*). The mould being dry, the workman must take a little of the finer stuff in his hands, and press a thin coat over the whole of the face of the mould, adding on the back that of a coarse quality, rubbing in small portions at a time, so that the ornament may be firm and solid. Immediately after squeezing, the ornament must be taken from the mould, cleaned up, and fixed in its place. When the mould has been used two or three times, it is liable to become damp, which prevents the impressions from leaving expeditiously; in this case, for the purpose of destroying its adherence, sprinkle a little fine flint-dust into the mould. These methods of moulding and casting may be applied not only to capitals, but also to all kinds of work in this composition, such as coats of arms, vases, foundations, figures, and busts, always taking the precaution never to allow the substance of artificial stone to exceed two inches and one half. For any greater thickness will be liable to injure in burning.

*Mastic* is intended for an external composition, possessing peculiar properties, which in some cases render it superior to Roman cement, having the power of resisting heat and frost, adhering to iron, copper, and even glass, with equal tenacity.

It is generally applied to the exteriors of mansions, but it may also be very beneficially used for laying the floors of halls, kitchens, &c.

Mastic is composed of pounded stone, silver sand, litharge, and red-lead, and when manufactured has the appearance of very fine sand. It will be perceived the manner of working mastic is entirely different from that of Roman cement.

To one hundred-weight of mastic add one gallon of linseed oil, and let them be well incorporated, which must be effected by treading them together with the feet until the amalgamation is complete, and must be continued until all the bright spots disappear; it will then be fit for use.

*The Manner of using Mastic.* The joints of the brick-work being well cleaned out, the work must be correctly plumbed up by means of flat-headed nails, and screeds for the guidance of the floating-rule formed with Roman cement, and kept about one inch in breadth. This being done, the bricks must be well saturated with boiled linseed oil of the best quality, and the mastic laid on with the hand and laying-trowel. The floating-rule is then passed carefully over the work, and when the space between the screeds is sufficiently filled up, it must be floated with a hand-float until it assumes the appearance of highly polished stone, the screeds then cut out, their places filled with mastic, and properly trowelled into the rest of the work.

These directions will be proper for large works, but where windows and doors occur, it will be necessary to attach strips of wood on to the reveals to project the thickness of the intended mastic-work, and when the preparations for forming the reveals by shifting the strip of wood to the outside of the plastering, projecting as before to guide the hickness of the reveals. When well trowelled the strips are taken off and nail-holes filled, and angles well cleaned down. Thus this process is completed.

*To run Mastic Mouldings.* In order to run mouldings with mastic, a mould of wood must be cut, in every way three eighths of an inch less than the intended moulding, the ground or inner part of the moulding being formed of pieces of broken bricks or tiles, and with the wooden mould run out with Roman cement and afterwards with mastic, the mastic mould being cut to the full size, the edges mounted with brass, iron, or copper. All ornaments executed in mastic must be cast in plaster-moulds similar to those used in figure-casting, without being seasoned in oil, but used in their dry state, and kept well polished with a linen cloth. All heavy ornaments for soffits and entablatures should be cut through the plastering to the brick-work in a dovetail form something less than the figure, and as many nails as convenient driven in the back of the figure, and the hole filled with Roman cement in a soft state, then the figure properly adjusted in its intended place. All small enrichments may be set with white-lead.

*Mastic Floors.* The groundwork being completely dry, and the bricks properly cleaned and saturated with boiled linseed oil, the screeds formed with Roman cement, for the purpose of floating or levelling, the mastic mortar between the screeds being about one half of an inch thick, then cut out the screeds and fill their places with mastic, and trowel it down level with the other work.

*Bailey's Composition.* This composition is a valuable invention, of recent date, and may be used with great advantage, without being injured by the action of frost, on the exterior of public or private buildings. This is composed of unslacked lime well ground to a fine powder, and kept in air-tight casks until used. It is prepared by adding one third of sharp and clean river-sand. Reduce it by clean water in the manner of preparing Roman cement.

# CHAPTER III.

## PRACTICAL GEOMETRY, ADAPTED TO MASONRY AND STONE-CUTTING.

### SECTION I.—On the Position of Lines and Points.

As the construction of every complex object in nature consists of certain combinations of the simple operations of geometry, and as positions cannot be understood without angles and parallel lines, it will be necessary to treat of the practical part of this science, at least as far as the operations of the positions of lines and points are concerned, in order to render the construction and the language of geometry familiar to the student in their applications to the principles of masonry.

#### PROBLEM I.

From a given point in a given straight line to draw a perpendicular.

*Plate* I. Let A B, *fig.* 1, be a given straight line, and *c* the given point. In A B take two equal distances, *c d* and *c e*. From *d*, as a centre, with any radius greater than *c d* or *c e*, describe an arc at *f*, and with the same radius, from the point *e*, describe another arc intersecting the former at *f*, and draw *f c*, and *f c* is the perpendicular required.

#### PROBLEM II.

From the one extremity of a straight line to draw a perpendicular.

*Fig.* 2. Let A B be the given straight line, and let it be required to draw a perpendicular from the extremity B. On one side of the line A B take any convenient point *c*; and from *c*, as a centre, with any radius that will cut the line, describe an arc *d* B *e*, intersecting A B in the point *d*; through *c* draw the diameter *d e*, and join *e* B, and *e* B is the perpendicular required.

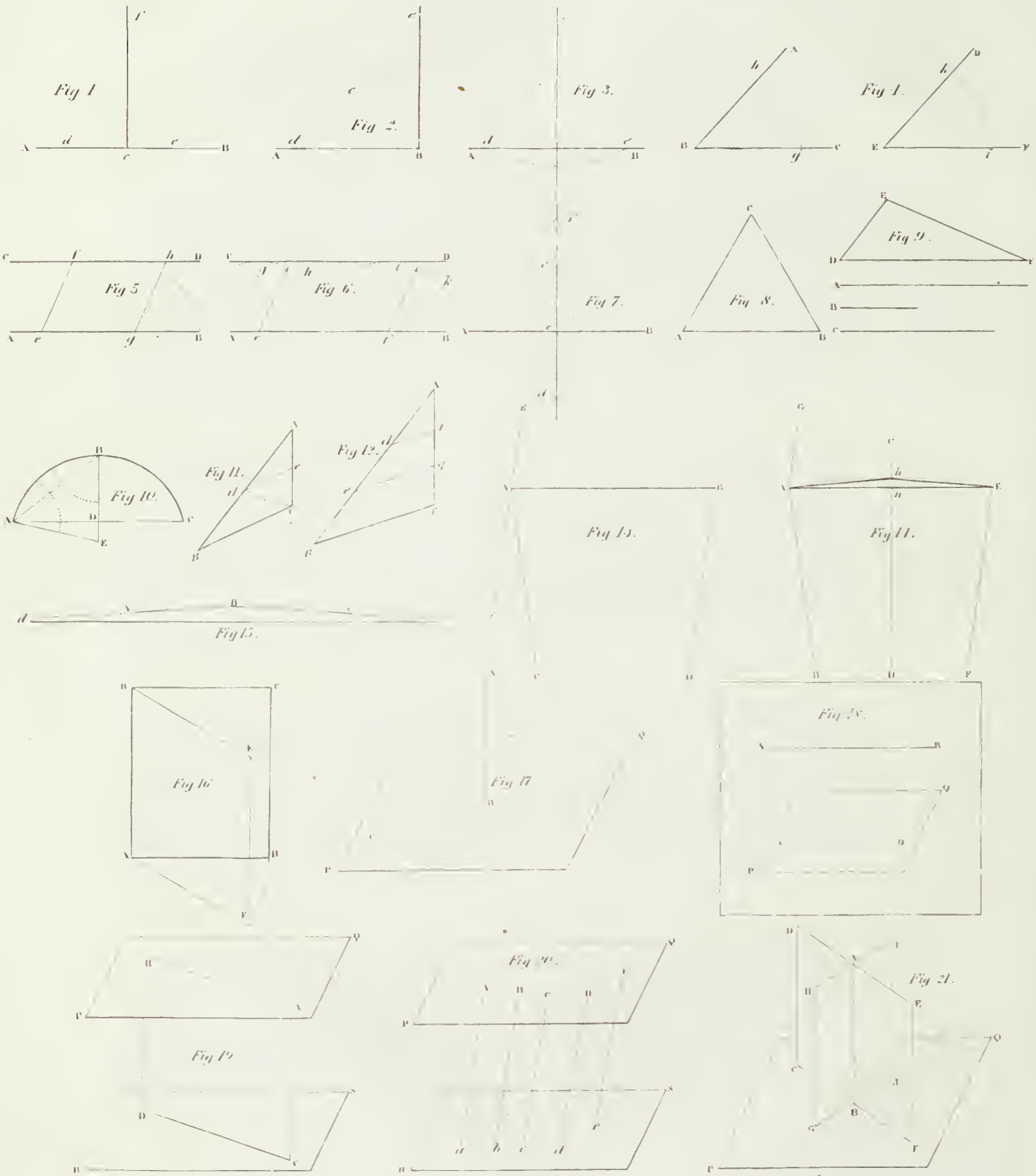
#### PROBLEM III.

From a given point out of a straight line to let fall a perpendicular.

*Fig.* 3. Let A B be the given straight line, and *c* the given point; it is required to draw a straight line from *c*, perpendicular to A B. From *c*, as a centre, with any distance that will cut the line A B, describe an arc intersecting A B in the points *d* and *e*; from *d*, as a centre, with any radius greater than the half of

Pl. I.

## LINES POINTS AND PLANES.



*d e*, describe an arc, and from *e*, with the same radius, describe another arc intersecting the former in *f*, and draw *f c*, and *f c* is the perpendicular required.

The criterion of the truth of the method of *fig.* 2 is that of the angle in a semicircle being a right angle.

### PROBLEM IV.

At a given point in a given straight line, to make an angle equal to a given angle.

*Fig.* 4. Let C B A be the given angle, and E F the given straight line. Let it be required to draw a straight line, at the point E, to make an angle with the line E F, equal to the angle C B A. From the point B, with any radius, describe an arc meeting B A in *h*, and B C in *g;* and from the point E, with the same radius, describe an arc *i k*, meeting E F in *i*. Make *i k* equal to *g h*, and through *k* draw the straight line E D, and F E D is the angle required.

### PROBLEM V.

Through a given point *f* to draw a straight line parallel to a given straight line A B.

*Fig.* 5. Let *f* be the given point, and A B the given straight line. Draw any straight line *f e*, meeting A B in *e*, and draw *g h*, making the angle *h g* B equal to *f e* B. Make *g h* equal to *e f*. Through the points *f* and *h* draw the line C D, and C D is parallel to A B, as required.

### PROBLEM VI.

To draw a straight line parallel to a given straight line at a given distance from the given straight line.

*Fig.* 6. Let A B be the given straight line; it is required to draw a straight line at a given distance from B C. In A B take any two points *e* and *f;* from *e*, with the given distance, describe an arc *g h;* and from *f*, with the same distance, describe another arc *i k*. Draw the line C D to touch the arcs *g h* and *i k*, and C D is parallel to A B, as required.

### PROBLEM VII.

To bisect a given straight line A B by a perpendicular.

*Fig.* 7. From the point A, as a centre, with any radius greater than the half of A B, describe an arc *c d;* and from B, with the same radius, describe another arc intersecting the former at *c* and *d*, and draw *c d*, intersecting A B in *e;* then A B is divided in *e*, as required.

### PROBLEM VIII.

Upon a given straight line to describe an equilateral triangle.

*Fig.* 8. Let A B be the given straight line. From the point A, with the radius A B, describe an arc, and from the point B, with the radius B A, describe another arc, intersecting the former in C, and draw the straight lines C A and C B; then A B C is the equilateral triangle required.

### PROBLEM IX.

Upon a given straight line to describe a triangle, of which the sides shall be equal to three given straight lines, provided that any one of the three given lines be less than the sum of the other two.

*Fig.* 9. Let the three given straight lines be A, B, C, and let D F be the straight line on which the triangle is required to be described. Make D F equal to the given straight line A. From D, with the radius of the line B, describe an arc, and from F, with the radius of the line C, describe another arc, meeting the arc described from D in the point E. Draw E D and E F, then D E F is the triangle required.

### PROBLEM X.

Given the base and height of the segment of a circle, to find the centre of the circle, and thence to describe the arc.

*Fig.* 10. Let A C be the base; bisect A C in D by the perpendicular B E; make D B equal to the height, and join the points A and B. Make the angle B A E equal to A B E, and the point E is the centre required.

From the point E, with the radius E A or E B, describe the arc A B C; then A B C is the arc required.

N. B. The centre must also have been found by bisecting A B by a perpendicular, which would have met B E in the point E.

### PROBLEM XI.

Given two converging lines, through a given point in one of them to draw a third straight line, so that the angles on the same side of the line thus drawn, made by this line and each of the first two given lines, may be equal to each other.

*Fig.* 13. Let the two converging lines be A C and B D, and let A be the given point. Draw A E parallel to B D; bisect the angle C A E by the straight line A B; then will the angles C A B and D B A be equal to one another.

For, suppose A E to be produced from A to F, and suppose A C and B D to be produced to meet in some point G, then A C would have been a line falling upon the two parallel straight lines A F and B D, and consequently making the angle at G equal to the angle F A C; and since the three angles of every triangle are equal to two right angles, and since the angles F A C, C A B, B A E, are also equal to two right angles, and since F A C is equal to the vertical angle of the triangle, the angle C A E is equal to the sum of the angles at the base; and therefore, since C A B is half the sum, the angle A B D must be equal to the other half.

### PROBLEM XII.

Given two converging lines, to describe the arc of a circle through a given point in one of them, without having recourse to a centre, so that the point of convergency may be in the centre of the arc.

*Fig.* 14. Let A B and E F be the two converging lines, and A the given point through which the arc is to pass. Draw A E, making the angles B A E and F E A equal to each other. Bisect A E by the perpendicular C D, and draw A *h* making the angles B A *h* and D *h* A equal to one another; then A *h* is the chord of the arc, and *n h* is the versed sine. Suppose now that the three points A, *h*, E, are transferred to A, B, C, *fig.* 15. Join B A and B C. Produce B A to *d*, and B C to *e*. Make the edge of a slip of wood to the angle *d* B *e*. Move the edge *d* B *e* of the slip of wood so that the point B may be upon A; then move this slip again, so that while the part B *d* of the edge of the slip is sliding upon the pin at A, and the part B *e* upon the pin at C, a pencil held to the angle B will describe a curve; then this curve will be the arc required.

### PROBLEM XIII.

Given two straight lines, to find a third proportional.

*Fig.* 11. From any point A, draw any two straight lines B A, A C, at any angle. Make A B equal to one of the given straight lines, and A C equal to the other; and in A B make A *d* equal to A C. Join B C and draw *d e* parallel to B C, meeting A C in *e;* then A *e* is the third proportional required.

Or, if A *e* be equal to one of the given straight lines, and A *d* equal to the other. Make A C equal to A *d*. Join *d e* and draw C B parallel to *ed;* then A B is the third proportional.

### PROBLEM XIV.

Given a straight line, and how divided, to divide another in the same proportion.

*Fig.* 12. Draw the lines B A, A C, as in the preceding problem, and let A B be the given divided line, *d* and *e* being the points of division, and let A C be the line to be divided. Join B C and draw *e g* and *d f* parallel to B C, meeting A C in *f* and *g;* then A C is divided in *f* and *g*, in the same proportion as A B is divided in the points *d* and *e*.

PROBLEM XV.

Given three straight lines, to find a fourth proportional.

*Fig.* 12. The angle B A C being made as before, let A *e* be equal to one of the given lines, A *d* equal to a second, and A *f* equal to the third. Join *d f* and draw *e g* parallel to *d f;* then A *g* is the fourth proportional.

## SECTION II. — On the Species, Nature, and Construction of Curve Lines.

The geometrial orders of lines employed in architecture, in the construction of arches, are circular and elliptic, and occasionally parabolic, hyperbolic, cycloidal, and catenarian curves.

In houses, the chief lines employed in the construction of arches and vaults are circular and elliptic curves, generally a semi, and sometimes less, but seldom or never greater. When a circular or elliptic arc is adopted, one of the axes of the curve is most frequently situated upon the springing line; but is sometimes placed so as to be parallel to it. The most usual portions of circular or elliptic curves are the semi; and in the pointed style of architecture, parabolic and hyperbolic curves are very frequently employed.

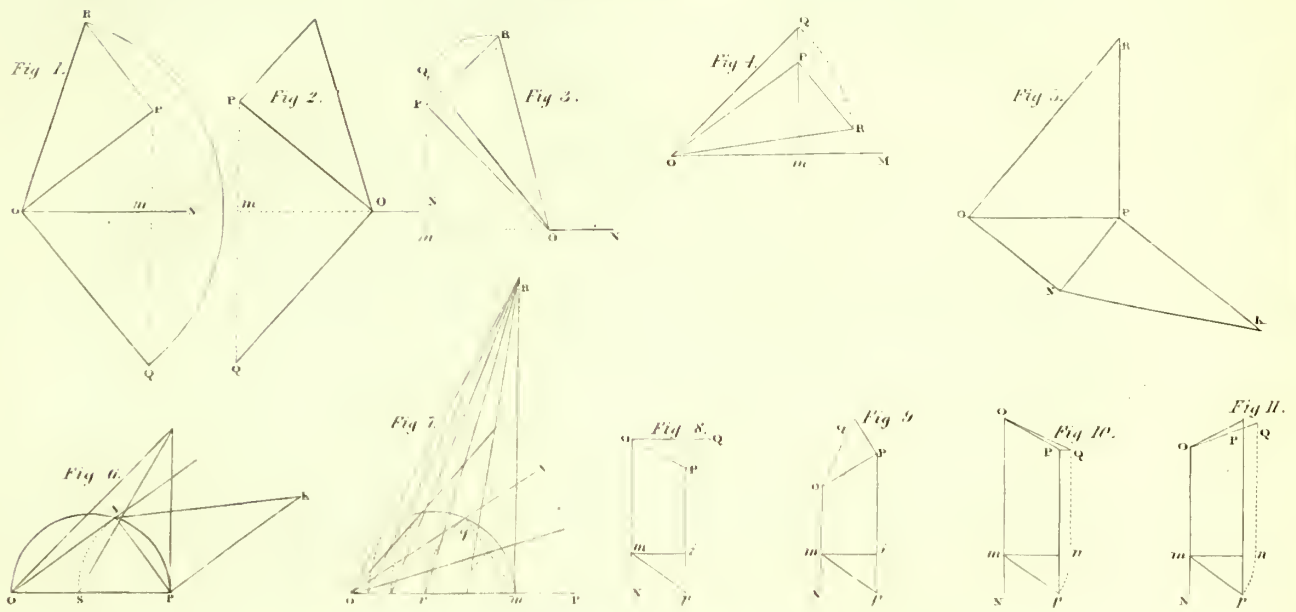
In bridge building, besides circular and elliptic curves, which are the most often used in the construction of stone arches, cycloidal curves may also be introduced. In chain bridges, or bridges of suspension, not only the circular and parabolic curves, but that of the catenarian may be employed. The suspending chains necessarily assume the form of catenarian curves; but the road-way may be any curve line whatever; but as all curves are nearly circular at the vertex, it will be better to employ those in the construction of works which are susceptible of the most easy calculation.

Among the numerous orders of curve lines, the parabolic affords the most easy means of computing its ordinates and tangents, which will be found necessary in ascertaining the rise and inclination of the road-way in all points of the curve, from either extreme to the centre of the bridge.

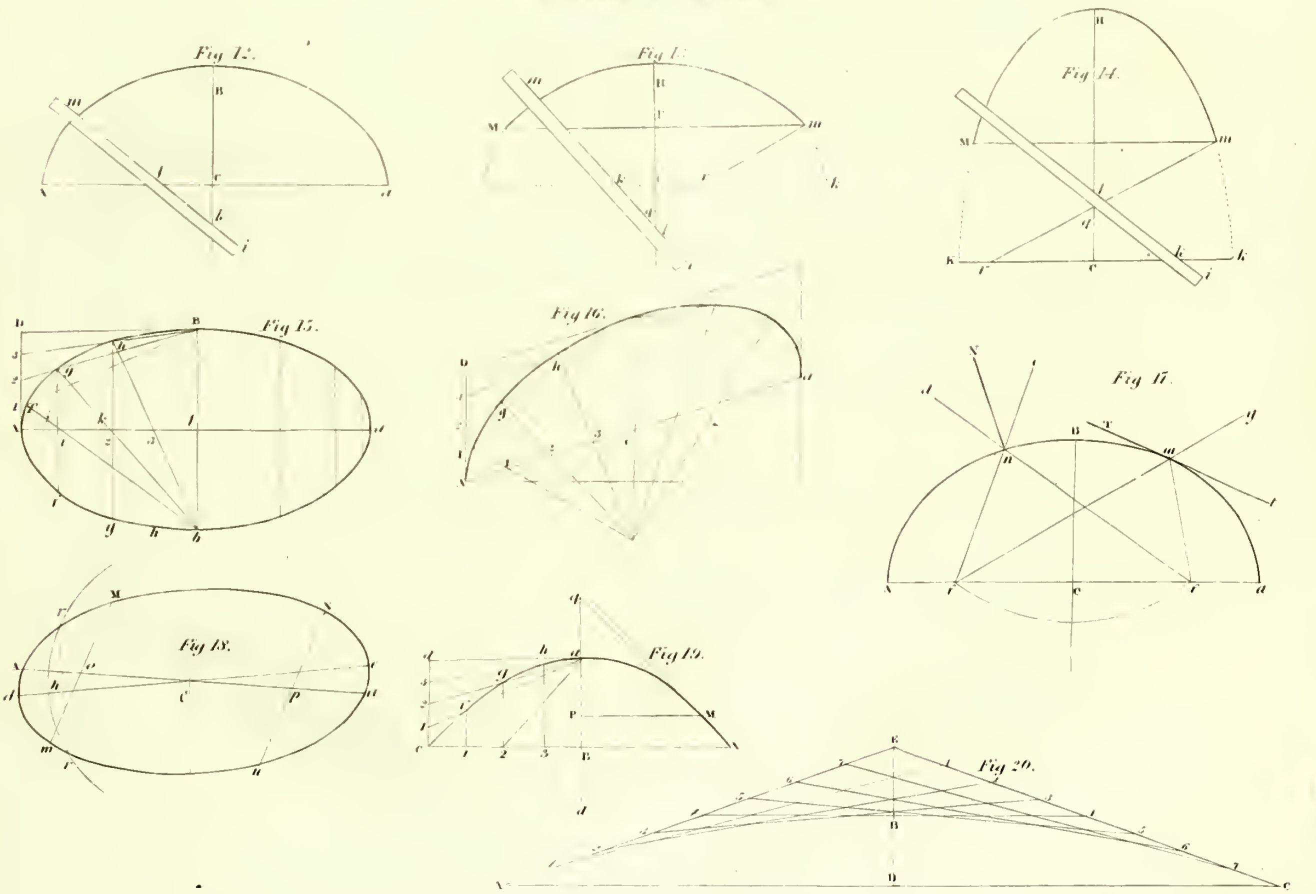
The base of an arc is that upon which the arc is supposed to stand; and the highest point of an arc is that in which a straight line parallel to the base would meet the curve, without the possibility of coming within the area included by the curve and its base, and this point is called the summit of the arc.

As the curves employed in building are generally symmetrical, therefore they

## TRIHEDRALS.




## CURVE LINES.

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are equal and similar on each side of the summit, and their areas are equal and similar on each side of the perpendicular from the middle of the base.

### PROBLEM I.

To describe a semi-ellipse upon the transverse axis.

*Plate* II. Let A *a*, *fig.* 12, be the axis major, and let B C, bisecting A *a* perpendicularly in the point C, be the semi-conjugate axis.

Upon the straight edge *m i* of a rule, mark the point *m* at or near one of its ends, and the point *l* at a distance from *m* equal to B C, the semi-conjugate axis, and the point *k* at a distance from *m* equal to A C or C *a*, the semi-transverse axis; the distance *k l* being equal to the difference of the two axes. To find any point in the curve, place the point *k* in the line B C produced, and the point *l* in the axis A *a*; and mark the paper or plane on which the figure is to be described at the point *m*. Proceed in this manner until a sufficient number of points are found, and draw a curve through them, and the curve will be the semi-ellipse required.

### PROBLEM II.

Upon a given double ordinate, to describe the segment of an ellipse to a given abscissa, and to a given semi-axis in that abscissa.

*Figs.* 13 and 14. Let M *m* be the double ordinate, P H the abscissa, and H C the semi-axis.

Through the centre C, draw K *k* parallel to M *m*. From either extremity *m* of the double ordinate as a centre, with the distance H C of the given semi-axis as radius, describe an arc intersecting K *k* in *r*. Draw *m r* intersecting H C in *q*, or produce *m r* and H C to meet in *q*; then *m q*, *fig.* 13, will be the semi-transverse, and *m r* the semi-conjugate, and in *fig.* 14, the contrary will take place; *m r* will be the semi-transverse, and *m q* the semi-conjugate; the two axes being thus found, the curve may be described as in the immediately preceding problem.

### PROBLEM III.

Given two conjugate diameters, to find any number of points in the curve, and thence to describe it.

*Figs.* 15 and 16. Let A *a*, B *b*, be the conjugate diameters. Draw A D parallel to B C, and B D parallel to C A. Divide A D and A C each into the same number of equal parts. Through the points of division in A C draw straight lines from *b*, and through the points of division in A D, draw other straight lines to the point B, meeting those drawn from *b* in the points *f*, *g*, *h*.

Draw a curve line through the points A, *f*, *g*, *h*, B, which will be one quarter of the whole figure. The other three will of course be found in the same manner.

PROBLEM IV.

To draw a normal, or line perpendicular to the curve of an ellipse at a given point in the curve.

*Fig.* 17. Let the curve be A B *a*, and let A *a* be the transverse axis, and C B the semi-conjugate, and let it be required to draw a line from the point *n* perpendicular to the curve. With A C the semi-axis major as a radius, from the point B describe an arc, intersecting A *a* in the foci *f*, *f′*. From the points *f*, *f′*, and through the point *n*, draw *f′ d* and *f e*, and bisect the angle *e n d*, and the bisecting line *n* N will be perpendicular to the curve as required.

PROBLEM V.

To draw a tangent to the curve of an ellipse at a given point.

*Fig.* 17. Let *m* be the given point. Draw *f m*, and produce *f m* to *g*, and join the points *f′*, *m*. Bisect the angle *f′ m g*, and the bisecting line T *t* will be the tangent required.

PROBLEM VI.

The curve of an ellipse being given, to find the two axes.

*Fig.* 18. Let A M N *n m* be the given curve within the figure; draw any two parallel lines M *m*, N *n*. Bisect M *m* in *o*, and N *n* in *p*, and draw the straight line A *o p a*. Bisect A *a* in C, from C as a centre, with any radius that will cut the curve; describe the arc *r r′*, intersecting the curve in the points *r r′*, and draw the straight line *r r′*. Bisect *r r′* in *h*, and through the points *h* and C draw the line *d e*, then *d e* is the axis major; and a line drawn through the point C at right angles to *d e*, to meet the curve on each side of C, will be the axis minor.

PROBLEM VII.

With a given abscissa and ordinate, to describe a parabola.

*Fig.* 19. Let A B be the abscissa, and B C the ordinate. Draw C D parallel to B A, and A D parallel to B C. Divide C D and C B each into the same number of equal parts. From the points 1, 2, 3, in C D, draw lines to A, and from the points 1, 2, 3, in C B, draw lines parallel to B A, meeting the former lines to A in the points *f*, *g*, *h*. Draw the curve C *f g h* A, which will be one half of the parabola; the other half will be found in the same manner. The radius of curvature at the point A is half the parameter.

### PROBLEM VIII.

The curve of a parabola being given, to find the parameter.

*Fig.* 19. Let C A N be the curve of the parabola. Bisect B C in the point 2, and draw A 2 and 2 *d* perpendicular to A 2, meeting A B produced in *d;* then B *d* is one fourth part of the parameter.

For A B : B 2 : : B 2 : B *d;* now let $AB = a$, $BC = b$, then $B2 = \frac{1}{2}b$; hence $a : \frac{1}{2}b :: \frac{1}{2}b : \frac{1}{4}p$; whence $ap = b^2$ or $p = \frac{b^2}{a}$.

### PROBLEM IX.

To draw a tangent to any point M, in the curve of a parabola.

*Fig.* 19. Draw the ordinate P M, and produce P A to *q*. Make A *q* equal to A P, and draw the straight line *q* M; then *q* M will be the tangent required.

For the subtangent of the curve is double to the abscissa.

### PROBLEM X.

To form the curve of a parabola by means of tangents.

*Fig.* 20. Let A C be the double ordinate. Draw D B bisecting A C, and make D B equal to the abscissa. Produce D B to E, and make B E equal to B D. Draw the two straight lines E A and E C. Divide A E and E C each in the same proportion, or into the same number of equal parts, at the points 1, 2, 3, &c., in each line. Draw the straight lines 1-1, 2-2, 3-3, &c., and their intersections will circumscribe the curve of the parabola as required.

*Scholium.* Small portions of the curves of conic sections, near to the vertices, may be described with compasses so as not to be perceptible; and thus, not only in the parabola, but in the ellipse; and in the hyperbola, the radius of curvature at the vertices is half the parameter, which passes through the focus. In the parabola, the parameter is a third proportional to the abscissa and ordinate; and in the ellipse and hyperbola, the parameter is a third proportional to the transverse and conjugate axis; and therefore may be easily found by lines or by calculation on large works, such as bridges, &c.

## SECTION III.— Of the Position of Lines and Planes, and the Properties arising from their Intersections.

A plane is a surface in which a straight line may coincide in all directions.

A straight line is in a plane, when it has two points in common with that plane.

Two straight lines which cut each other in space, or would intersect if produced, are in the same plane; and two lines that are parallel are also in the same plane.

Three points given in space, and not in a straight line, are necessary and sufficient for determining the position of a plane. Hence two planes, which have three points common, coincide with each other.

The intersection of two planes is a straight line.

*Plate* I. When two planes A B C D, A B E F, *fig.* 16, intersect, they form between them a certain angle, which is called the inclination of the two planes, and which is measured by the angle contained by two lines; one drawn in each of the planes perpendicular to their line of common section.

Thus, if the line A F, in the plane A B E F, be perpendicular to A B, and the line A D, in the plane A B C D, be perpendicular also to A B, then the angle F A D is the measure of the inclination of the planes A B E F, A B C D. When the angle F A D is a right angle, the two planes are perpendicular.

*Fig.* 17. A line A B is perpendicular to a plane P Q, when the line A B is perpendicular to any line B C, in the plane P Q, which passes through the point B, where the line meets the plane. The point B is called the foot of the perpendicular.

A line A B, *fig.* 18, is parallel to a plane P Q, when the line A B is parallel to another straight line C D, in the plane P Q.

If a straight line have one of its intermediate points in common with a plane, the whole line will be in the plane.

Two planes are parallel to one another when they cannot intersect in any direction.

The intersections of two parallel planes with a third are parallel. Thus, in *fig.* 19, the lines A B, C D, comprehended by the parallel plane P Q, R S, are parallel.

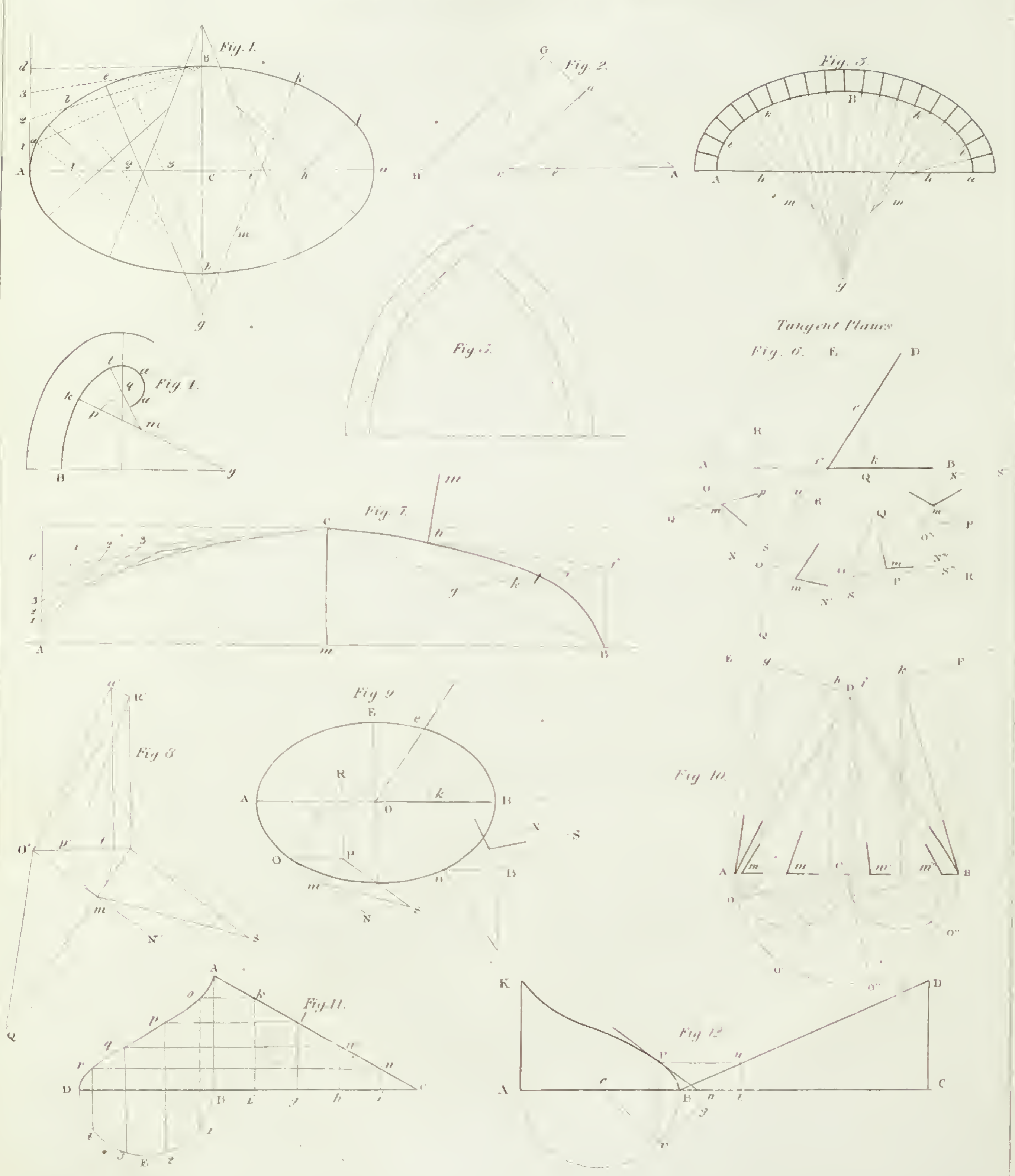
Any number of parallel lines comprised between two parallel planes are all equal. Thus the parallel lines A *a*, B *b*, C *c*, . . . ., *fig.* 20, comprised by the parallel planes P Q, R S, are all equal.

If two planes C D E F, G H I J, *fig.* 21, are perpendicular to a third plane P Q, their intersection A B will be perpendicular to the third plane P Q.

If two straight lines be cut by several parallel planes, these straight lines will be divided in the same proportion.

Pl 3.

# RIGHT SECTIONS OF ARCHES.

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## SECTION IV. — Of the Right Sections of Arches or Vaults.

### PROBLEM I.

To describe the arc of a circle which shall have a given tangent at a given point, and which shall touch another given arc.

*Plate* III. Let B *k*, *fig.* 4, be one of the given arcs, and *l a u* the other, and let it be required to describe the arc of a circle, which shall touch the arc B *k* in the point *k*, and the arc *l a u* in some point to be found; let *g* be the centre of the arc B *k*.

Draw *g k*, and make *k p* equal to the radius of the circle *l a u*. Draw a straight line from *p* to *q*, the centre of the arc *l a u*, and bisect *p q* by a perpendicular, meeting *k g* in *m*. Join the points *m*, *q*, and prolong *m q* to *l*. It is manifest that *m k* and *m l* are equal; therefore, from *m*, with the radius *m k* or *m l*, describe an arc *k l;* and *k l* will be the arc required.

### PROBLEM II.

To describe an oval, representing an ellipse, to any given dimensions of length and breadth, given in position.

Let A *a*, B *b*, *fig.* 1, be the two given lines bisecting each other in C; A *a* being equal to the length, and B *b* to the breadth.

Find a third proportional to this semi-axis C *a*, C B,* and make *a h* equal to the third proportional; also find a third proportional to C B, C *a*, † and make B *g* equal to the third proportional.

Make the angle B *g k* equal to about 15°, and let *g k* meet A *a* in the point *i*. From *g*, with the radius *g* B, describe an arc B *k*, and from *h*, with the radius *h a*, describe an arc *l a*. Describe the arc *k l* by the preceding problem to touch the arc B *k* in *k*, and to touch the arc *a l* at *l*, and thus one quarter of the oval will be completed; the other three will be found by placing the centres in their proper positions.

Three or more points *a*, *b*, *c*, might easily have been found in the curve. Thus, draw A *d* parallel to B *b*, and B *d* parallel to C A. Divide A *d* into four equal parts, and divide A C also into four equal parts at 1, 2, 3. From *b* and through 1, 2, 3, in C A, draw *b a*, *b b*, *b c*, and from the points 1, 2, 3, in A *d*, draw towards B, to intersect the former in *a*, *b*, *c*, so that we may find the radius of

* Thus, in *fig.* 2, draw the two lines G A, A H, making an angle with each other; make *a c* equal to *a* C, *fig.* 1, and A *d* equal to C B, *fig.* 2; and make A *e* equal to A *d*. Join *c d*, and draw *e f* parallel to *c d;* then *a f* is the third proportional.

† That is, in *fig.* 2, make A *c* equal A G or *a* C, *fig.* 1, and A *d* equal to C B or C *b*, *fig.* 1, and make A G equal to A *c*, and join *c d*. Draw G H parallel to *d c;* then A H is the third proportional.

curvature upon the sides, and at the two ends, by finding the centre of a circle passing through three points at each extremity, the extremity being the middle point.

*Fig.* 3 exhibits the use of this method of describing an oval, in finding the direction of the joints of arches so as to agree with the normals drawn from the several divisions of the inner arc. The arcs are marked the same as in *fig.* 2.

REMARK.

When the height of the arch is equal to or greater than half the span, and when it is not necessary that the vertical angle should be given, the curves of the intrados and extrados on the one side may be described from the same centre, as also those of the other side from another centre.

The most easy Gothic arch to describe is that of which the height of the intrados is such as to be the perpendicular of an equilateral triangle, described upon the sparing line as a base, and these centres are the points to which the radiating joints must tend.

Gothic arches seldom exceed in height the perpendicular of the equilateral triangle inscribed in the intrados of the aperture; but when the arch is surmounted and the height less than the perpendicular of the equilateral triangle made upon the base, draw a straight line from one extremity of the base to the vertex, and bisect this line by a perpendicular. From the point where the perpendicular meets the base of the arch, and with a radius equal to the distance between this point and the extremity of the base joined to the vertex, describe an arc between the two points, joined by the straight line, and the curve which forms one side of the intrados will be complete. In the same manner will be found the curve on the other side, (see *fig.* 5,) so that by only two centres the whole of the intrados will be formed.

The curves of all kinds of Gothic arches whatever may be described by means of conic parabola, to a given vertical angle, and to any given dimensions. Thus, in *fig.* 7, let C *e*, C *f*, be the two tangents, and A *e*, and B *f*, the heights of their extremities. Divide A *e* and *e* C each into the same number of equal parts by the points 1, 2, 3, in each of these lines. Draw lines from the corresponding points 1-1, 2-2, 3-3, &c.; and the intersections will form the curve of one side of the intrados, as we have already seen. The curve on the other side will be formed in the same manner.

Join B C, and bisect it in *g*, and join *g f*, intersecting the curve in *l*. Draw *h k* parallel to C B, meeting *g f* in *k*. Make *l i* equal to *l k*, and *i h* joined is a tangent at *h*. Hence, *h m* perpendicular to *h i* is the joint.

# CHAPTER IV.

## SECTION I. — On the Nature and Construction of Trehedrals.

### DEFINITIONS.

Every stone bounded by six quadrilateral planes or faces forms a solid, of which the surfaces terminate on eight points, every three surfaces in one point. Every three planes thus terminating is termed a *solid angle* or *trehedral.*

The angles formed by the intersections of the faces with one another, or the three plane angles, are called sides of the trehedral, and the angles of inclination are called, by way of distinction from the other, simply *angles.*

The three sides, as well as the three angles, are each called a *part;* so that the whole trehedral consists of six parts; and if any three of these parts be given, the remaining three can be found.

Therefore, in bodies constructed of stone, which are intended to have their solid angles to consist of three plane angles, the construction of such bodies may be reduced to the consideration of the trehedral.

As to the remaining surface of the solid which incloses the solid, completely making a fourth side to the trehedral, it may be of any form whatever, regular or irregular, or consisting of many surfaces ; it or they have nothing to do in the construction.

The parts of the trehedral, which may be obtained from three given parts, are the very same as three parts found in a spherical triangle from three given parts. This is, in fact, the same as spherical trigonometry.

We shall not, however, enter into any operose analytical investigations, but treat the subject in the most simple manner, according to the rules of solid geometry ; and only those trehedrals, which have two of their planes at a right angle with each other (though there are many cases in which the oblique trehedral would be necessary) ; as the bounds prescribed for this work will not admit of such an extension of the principles.

If the trehedral have two of its planes perpendicular to each other, it is called a *right-angled trehedral;* each of the two faces thus forming a right angle is called a *leg*, and the remaining side, joining each leg, is called the hypothenuse.

### PROBLEM I.

Given two legs of a right-angled trehedral, to find the hypothenuse.

*Plate* II., *figs.* 1, 2, 3, and 4. Let P O N and P O R be the given legs. Draw P R perpendicular to O P, and P Q perpendicular to O N. From O, as a centre, with the radius O R, describe an arc intersecting P Q in Q, and join O Q, and Q O N is the hypothenuse required.

*Demonstration.* — Suppose the triangle P O R revolved upon O P, until P R become perpendicular to the plane of the triangle O P N, then the plane of the triangle O P R will be perpendicular to the plane of the triangle O P N.

Again, suppose the triangle O N Q to revolve upon O N, and let P Q, or P Q produced, intersect O N in *m*, then *m* Q will always be in a plane passing through P *m* and the plane described by *m* Q will be perpendicular to the plane *m* O P; and as P R is, by supposition, also perpendicular to the plane *m* O P, therefore P R and *m* Q being thus situated in the same plane will meet, except they are parallel.

Let *m* Q therefore be revolved until the straight line *m* Q fall upon the point R; let Q then be supposed to coincide with R, then because Q, by supposition, coincides with R, and the point O is common to the straight lines O Q and O R, therefore the straight lines O Q and O R having two common points will coincide, and therefore *m* O Q will be the hypothenuse required.

PROBLEM II.

Given the hypothenuse and one of the legs, to find the other leg.

*Figs.* 1, 2, 3, and 4. Let N O Q be the given hypothenuse, and N O P the given leg, and let these two parts be attached to each other by the straight line O N.

In O N take any point *m*, and through *m* draw P Q perpendicular to O N. Draw P R perpendicular to O P. From the point O, with the radius O Q, describe an arc Q R and join O R; then will P O R be the other leg, as required.

These four diagrams show the various positions in which the data may be placed; every one will frequently occur in practice.

PROBLEM III.

Given the two legs of a right-angled trehedral, to find one of the angles at the hypothenuse.

*Figs.* 5 and 6. Let the two given legs be P O N and P O R. In O P take any point P, and draw P N perpendicular to O N, and P R perpendicular to P O, and P K parallel to O N. Make P K equal to P R, and join N K; then P N K will be the angle at the hypothenuse.

In *fig.* 5, the two legs lie upon separate parts; and in *fig.* 6, one of the legs lies upon the other.

*Fig.* 7 exhibits the same principle applied in finding a series of bevels or angles made by the hypothenuse and a leg. Thus let the two legs be P O N and P O R. From any point *m*, in O P, draw *m* R perpendicular to O P. On O *m*, as a diameter, describe the semicircle O *q m*, intersecting O N in *q*, and join *q m*. Make *m r* equal to *m q*, and join *r* R; then P *r* R will be the angle required.

### PROBLEM IV.

Given one of the legs and the inclination of the hypothenuse to that leg, to find the other leg.

*Figs.* 8 and 9. Let N O P be the given leg. In O N take any point *m*, and draw *m i* perpendicular to O N. Make *i m p* equal to the angle which the leg N O P makes with the hypothenuse. Through any point *i*, in *m i*, draw P*p* parallel to O N, and P Q, perpendicular to O P. Make P Q equal to *i p*, and join O Q, and Q O P will be the other leg.

### PROBLEM V.

Given one of the legs and the angle which the hypothenuse forms with that leg, to find the hypothenuse.

*Figs.* 10 and 11. In N O, take any point *m*, and draw *m n* perpendicular to O N. Make *n m p* equal to the angle which the hypothenuse makes with the leg N O P. From the point *m* as a centre, with any radius *m n*, describe an arc *n p*. Draw *p* P, *n* Q parallel to N O, and P Q perpendicular to N O, and join O Q; then N O Q is the hypothenuse required.

### GENERAL APPLICATIONS OF THE TREHEDRAL TO TANGENT PLANES.

Example I. — Given the inclination and seat of the axis of an oblique cylinder or cylindroid, to find the angle which a tangent makes at any point in the circumference of the base with the plane of the base.

*Plate* III., *figs.* 6 and 9. Let A E B O be the base of the cylinder or cylindroid, C B the seat of the axis, and let B C D be the angle of inclination, and let O be the point where the tangent plane touches the curved surface of the solid.

Draw O N, a tangent line, at the point O in the base, and draw O P parallel to C B. Make the angle P O R equal to B C D, and draw P R perpendicular to P O.

Then, if the triangle P O R be conceived to be revolved round the line P O as an axis, until its plane become perpendicular to the plane of the circle A E B C, the straight line O R will, in this position, coincide with the cylindrical surface, and a plane touching the cylinder or cylindroid at O will pass through the lines O N and O R. Here will now be given the two legs P O R and P O N of a right-angled trehedral to find the angle which the hypothenuse makes with the base. Draw P Q perpendicular to O N, intersecting it in *m*, and draw P S perpendicular to P Q. Make P S equal to P R, and join *m* S; then P *m* S is the angle required.

The hypothenuse will be easily constructed at the same time, thus: — make *m* Q equal to *m* S, and join O Q, then N O Q will be the hypothenuse required.

In *fig.* 1, the method of finding the angle which the tangent plane makes with the base and the hypothenuse is exhibited at four different points. In the two first points O from A in the first quadrant, the tangent planes make an acute angle at each point O; but in the second quadrant, they make an obtuse angle at each point O.

*Fig.* 8 is the second position of the construction from the point A, for finding the angle which the tangent plane makes with the base, and for finding the hypothenuse enlarged; in order to show a more convenient method by not only requiring less space, but less labor. It may be thus described, the two given legs being P′ O′ R′ and P′ O′ N′.

Draw P′ *m*′ perpendicular to O′ N′, meeting O N in *m*′. In P′ O′, make P′ *v*′ equal to P′ *m*′, and draw the straight line *v*′ R′, then P′ *v*′ R′ will be the inclination of the tangent plane at the point O.

Again, in O′ P′ make O′ *t*′ equal to O′ *m*′, and draw *t*′ *u*′ parallel to P′ R′. From O′, with the radius O′ R′, describe an arc meeting *t*′ *u*′ in *u*′, and draw the straight line O′ *u*′; then *t*′ O′ *u*′ is the hypothenuse.

For since P′ S′ is equal to P′ R′, and P′ *v*′ equal to P′ *m*′, and the angles *m*′ P′ S′ and *v*′ P′ R′ are right angles; therefore the triangle *v*′ P′ R′ is equal to the triangle *m*′ P′ S′, and the remaining angles of the one equal to the remaining angles of the other, each to each; hence the angle P′ *v*′ R′ is equal to the angle P′ *m*′ S′.

Again, because O′ *t*′ is equal to O′ *m*′, and O′ Q′ is equal to O′ R′, and O′ *u*′ is also equal to O′ R′; therefore O′ *u*′ is equal to O′ Q′, and since the angles O′ *t*′ *u*′ and O′ *m*′ Q′ are each a right angle, therefore the two right-angled triangles have their hypothenuses equal to each other, and have also one leg in each, equal to each other; therefore the remaining side of the one triangle is equal to the remaining side of the other, and therefore also the angles which are opposite to the equal sides are equal; hence the angle P′ O′ *u*′ is equal to N′ O′ Q′.

By considering this construction by the transposition of the triangles, the whole of the angles which the tangent planes make at a series of points O in *figs.* 6 and 9, and their hypothenuses, may be all found in one diagram, as in *fig.* 4.

Thus, in *fig.* 10, if the angles A C O, A C O′, A C O″, A C O‴, be respectively equal to A C O, A C O,′ A C O,″ A C O‴, *fig.* 6, and in *fig.* 10, the semicircle

A O′ B be described, and if C D be drawn perpendicular to A B, and the angles C A D, C B D, be made equal to B C D, *fig.* 6; then each half of *fig.* 10 being constructed as in *fig.* 8, the angles at $m$, $m'$, $m''$, $m'''$, will be respectively equal to the angle P $m$ S, P′ $m'$ S′, Q″ $m''$ S″, Q″ $m'''$ S″, in *fig.* 6.

Also, in *fig.* 10, the angles C A E, C A $g$, C A $h$, C B $i$, C B $k$, C B F, will be the hypothenuses at the point A, O, O′, O″, O‴, B, in *fig.* 6.

We may here observe, *fig.* 6, that the angles which the tangent planes make with the plane of the base in the first quadrant are acute; and those in the second quadrant are obtuse, and are the supplements of the angles P $m$ S; and, moreover, that all the angles which constitute the hypothenuses of the trehedral are acute, whether in the first quadrant or second quadrant of the semicircle A O B.

## SECTION II. — On the Projection of a Straight Line bent upon a Cylindric Surface, and the Method of Drawing a Tangent to such a Projection.

### PROBLEM I.

Given the development of the surface of the semi-cylinder, and a straight line in that development, to find the projection of the straight line on a plane passing through the axis of the cylinder, supposing the development to encase the semi-cylindric surface.

*Fig.* 11. Let A B C be the development of the cylindric surface, B C being the development of the semi-circumference, and let A C be the straight line given.

Produce C B to D, making B D equal to the diameter of the cylinder. On B D, as a diameter, describe the semicircle B E D, and divide the semicircular arc B E D into any number of equal parts, at 1, 2, 3, &c.; and its development B C into the same number of equal parts, at the points $f$, $g$, $h$, &c. Draw the straight lines $f\,k$, $g\,l$, $h\,m$, &c., parallel to B A, meeting A C at the points $k$, $l$, $m$, &c.; also, parallel to B A, draw the straight lines 1 $o$, 2 $p$, 3 $q$, &c., and draw $k\,o$, $l\,p$, $m\,q$, &c., parallel to C D; and the points $o$, $p$, $q$, &c., are the projections or seats of the points $k$, $l$, $m$, &c., in the development of the straight line A C.

The projection of a screw is found by this method: — B D may be considered as the diameter of the cylinder from which the screw is formed; and the angle B A C the inclination of the thread with a straight line on the surface; or B C A the inclination of the thread with the end of the cylinder. The same principle also applies to the delineations of the hand-rails of stairs, and in the construction of bevel bridges.

### PROBLEM II.

Given the entire projection of a helix or screw, in the surface of a semi-cylinder, and the projection of a circle in that surface perpendicular to the axis, upon the plane passing through the axis to draw a tangent to the curve at a given point.

*Fig.* 12. Let B P K be the projection of the helix or screw, and B A the projection of the circumference of a circle, and since this circle is in a plane perpendicular to the plane of projection, it will be projected into a straight line A B, equal to the diameter of the cylinder.

On A B as a diameter, describe the semicircle A *r* B, and draw P *r* perpendicular to and intersecting AB in *q*, join the points *e*, *r*, and produce *e r* to *f*.

Produce A B to C, so that B C may be equal to the semicircular arc B *r* A. Draw C D perpendicular to B C, and make C D equal to A K, and draw the straight line B D; then B D will be the development of the curve line B P K.

Draw P *u* parallel to A C, meeting B D in *u*, and draw *u t* perpendicular to B C. Draw *r g* perpendicular to *e r*, and make *r g* equal to B *t*. Draw *g n* perpendicular to A C, meeting B C in *n*, and draw the straight line *n* P; then *n* P will touch the curve at the point P.

Or the tangent may be drawn independent of B C D thus: — Draw P *r* perpendicular to AB, and *r g* a tangent at *r*. Make *r g* equal to the development of *r* B, and draw *g n* perpendicular to B C, meeting B C in *n*, and join *n* P, which is the tangent required.

## SECTION III. — Application of Geometry to Planes and Elevations, and also to the Construction of Arches and Vaults.

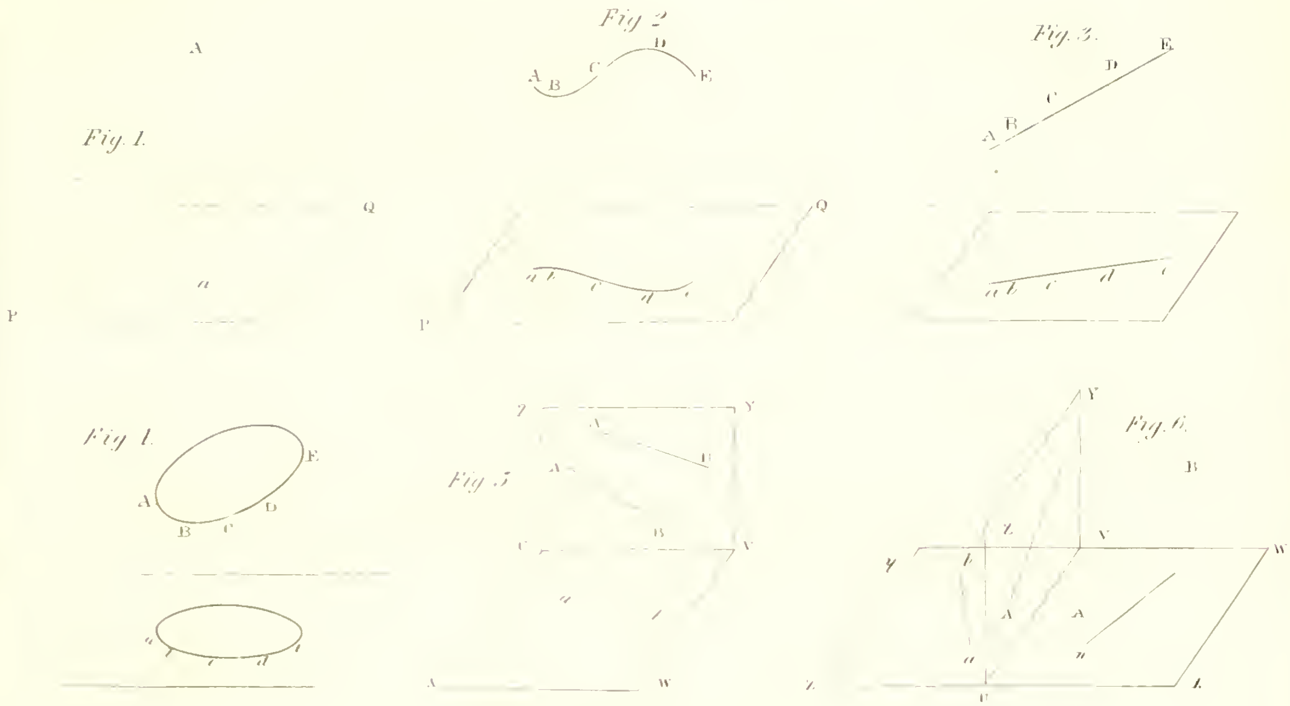
### PRELIMINARY PRINCIPLES OF PROJECTION.

If from a point A′, *Plate* IV., *fig.* 1, in space, a perpendicular A′*a* be let fall to any plane P Q whatever, the foot *a* of this perpendicular is called the *projection* of the point A′ upon the plane P Q.

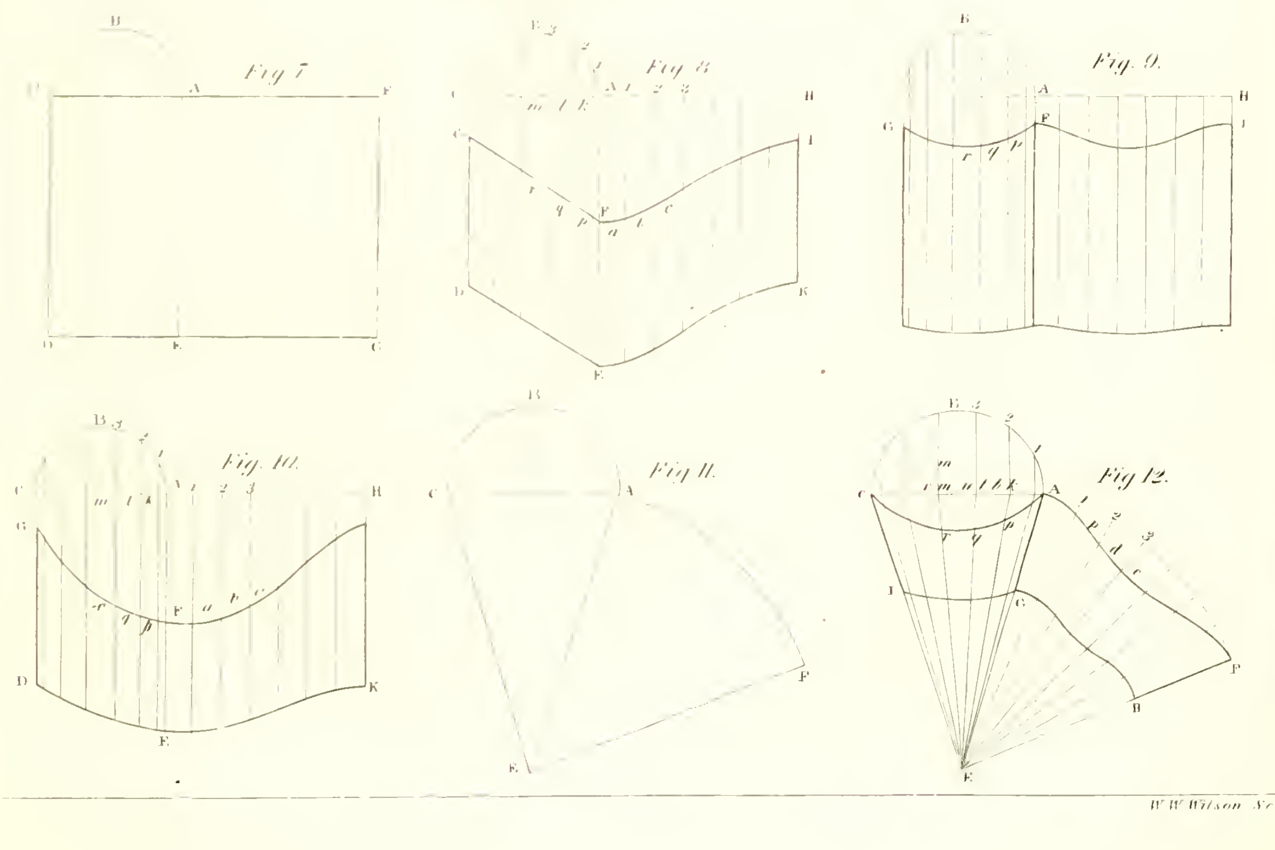
If through different points A′, B′, C′, D′, . . . . . *figs.* 2, 3, 4, of any line A′ B′ C′ D′ . . . . . whatever in space, perpendiculars A′*a*, B′*b*, C′*c*, D′*d*, . . . . . be let fall upon any plane P Q whatever, and if through *a*, *b*, *c*, *d*, . . . . . the projection of the points A′, B′, C′, D′, . . . . . in the plane P Q, a line be drawn, the line thus drawn will be the projection of the line A′ B′ C′ D′ . . . . . given in space.

If the line A′ B′ C′ D′ . . . . . *fig.* 3, be straight, the projection *a b c d* . . . . . will also be a straight line; and if the line A′ B′ C′ D′ . . . . . *fig.* 2, be a curve not in a plane perpendicular to the plane P Q, the curve *a b c d* . . . . . which is the pro-

# PRINCIPLES OF PROJECTION.




Surfaces of Solids

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jection of the curve A′ B′ C′ D′ . . . . . in space, will be of the same species with the original curve, of which it is the projection. Hence, in this case, if the original curve A′ B′ C′ D′ . . . . be an ellipse, a parabola, a hyperbola, &c., the projection *a b c d* . . . . will be an ellipse, a parabola, a hyperbola, &c. The circle and the ellipse being of the same species, the projected curve may be a circle or ellipse, whether the original be a circle or ellipse, as in *fig.* 4.

The plane in which the projection of any point, line, or plane figure is situated, is called the plane of projection, and the point or line to be projected is called the primitive.

The projection of a curve will be a straight line when the curve to be projected is in a plane perpendicular to the plane of projection. Hence the projection of a plane curve is a straight line.

If a curve be situated in a plane which is parallel to the plane of projection, the projection of the curve will be another curve equal and similar to the curve of which it is the projection.

The projection upon a plane of any curve of double curvature whatever is always a curve line.

In order to fix the position and form of any line whatever in space, the position of the line is given to each of two planes which are perpendicular to each other; the one is called the horizontal plane and the other the vertical plane; the projection of the line in question is made on each of these two planes, and the two projections are called the two projections of the line to be projected.

Thus we see, in *fig.* 5, where the parallelogram U V W X represents the horizontal plane, and the parallelogram U V Y Z represents the vertical plane, the projection *a b* of the line A′ B′ in space upon the horizontal plane U V W X is called the *horizontal projection*, and the projection A B of the same line upon the vertical plane U V Y Z is called the *vertical projection.*

The two planes upon which we project any line whatever are called the planes of projection.

The intersection U V of the two planes of projection is called the groundline.

When we have two projections *a b*, A B, of any line A′ B′ in space, the line A′ B′ will be determined by erecting to the planes of projection the perpendiculars *a* A′, B *b*′. . . ., A A′, B B′. . . . through the projections *a*, *b*, . . . . ; A, B, . . . . of the original points A′, B′, . . . . of the line in question. For the perpendiculars *a* A′, A A, erected from the projections *a*, A, of the same point A′, will intersect each other in space in a point A′, which will be one of these in the line in question. It is clear that the other points must be found in the same manner as this which has now been done.

When we have obtained the two projections of a line in space, whether immediately from the line itself, or by any other means whatever, we must abandon this line in order to consider its two projections only. Since, when we design a working drawing, we operate only upon the two projections of this line that we have brought together upon one plane, and we no longer see any thing in space.

However, to conceive that which we design, it is absolutely necessary to carry by thought the operations into space from their projections. This is the most difficult part that a beginner has to surmount, particularly when he has to consider at the same time a great number of lines in various positions in space.

The perpendicular A′ *a*, *fig*. 5, let fall from any point A whatever in space upon the plane X V of projection, is called the projectant of the point A′ upon this plane. Moreover, the perpendicular distance between the point A′ and the horizontal plane X V is called the projectant upon the horizontal plane, or simply the horizontal projectant; and the perpendicular distance A′ A between the original point A′ and the vertical plane U Y is called the projectant upon the vertical plane, or simply the vertical projection.

We shall remark, so as to prevent any mistake, that the horizontal projectant A′*a* is the perpendicular let fall from the original point upon the horizontal plane, and that the vertical projectant is the perpendicular let fall from that point upon the vertical plane. Hence the horizontal projectant is parallel to the vertical plane, and is equal to the distance between the original point and the horizontal plane; and the vertical projectant is parallel to the horizontal plane, and is equal to the distance between the original point and the vertical plane.

We may remark, that if through *a*, *fig*. 6, the horizontal projection of the point A′, we draw a perpendicular *a* a to U V, the ground-line, this perpendicular *a* a will be equal to the measure of the vertical projectant A′ A; consequently the distance of the point A′ to the vertical plane is equal to the distance between *a*, its horizontal projection, and U V, the ground-line, measured in a perpendicular to U V. In like manner, if through A, the vertical projection of the point A′, we draw a perpendicular A *a* to U V, the ground-line, this perpendicular A *a* will be equal to the measure of the horizontal projectant A *a*; consequently, the distance of this point A′ to the horizontal plane is equal to the distance between A, its vertical projection, and U V, the ground-line, measured in a perpendicular to U V.

To these very important remarks we shall add one which is not less so. Two perpendiculars, *a* a, *fig*. 6, A a, being let fall from the projections *a*, A, to the same point A′, upon the ground-line U V, will meet each other in the same point a of the said ground-line U V.

If we now wished the two projections of a point A′, *fig*. 6, or of any line A′ B′ whatever, to be upon one or the same plane, it is sufficient to imagine the vertical plane U V Y Z to turn round the ground-line U V, in such a manner as to be the prolongation of the horizontal plane U V W X; for it is clear that this plane will carry with it the vertical projection A or A B of the point, or of the line in question. Moreover, we see, and it is very important, that the lines A a, B b, perpendicular to the ground-line U V will not cease to be so in the motion of the plane U V Y Z; and, as the corresponding lines *a* a, *b* b, are also perpendiculars to the ground-line U V, it follows that the lines a *a'*, b *b'*, will be the respective prolongation of the lines *a* a, *b* b.

Hence it results, when we consider objects upon a single plane, that the projections *a*, A, of the point A' in space are necessarily upon the same perpendicular A *a* to the ground-line U V.

It is necessary to call to mind, that the distance A a measures the distance from the point in space to the horizontal plane (the point A being the vertical projection of this point), and that the line *a* a measures the distance from the same point in space to the vertical plane.

It follows, that if the point in space be upon the horizontal plane, its distance with regard to this last named plane will be zero or nothing, and the vertical A a will be zero also. Moreover, the vertical projection of this point will be upon the ground-line at the foot a of the perpendicular *a* a let fall upon the ground-line from the horizontal projection *a* of this point.

Again, if the point in space be upon the vertical plane, its distance, in respect of this plane, will be zero, the horizontal *a* a will be zero, and the horizontal projection of the point in question will be the foot a of the perpendicular A a let fall upon the ground-line from the vertical projection A of this point.

In general, we suppose that the vertical projection of a point is above the ground-line, and that the horizontal projection is below; but from what has been said, it is evident that if the point in space be situated below the horizontal line, its vertical projection will be below the ground-line; for the distance from this point to the horizontal plane cannot be taken from the base line to the top, but from the top to the base with respect to its plane.

So, if the point in space be situated behind the vertical plane, its horizontal projection will be above the ground-line, from which we conclude, —

1st. If the point in question be situated above the horizontal plane, and before the vertical plane, its vertical projection will be above, and its horizontal projection below, the ground-line.

2d. If the point be situated before the vertical plane, and below the horizontal plane, the two projections will be below the ground-line.

3d. If the point be situated above the horizontal plane, but behind the vertical plane, the two projections will be above the ground-line.

4th. Lastly. If the point be situated above the horizontal plane, and behind the vertical plane, the vertical projection will be below, and the horizontal projection above, the ground-line.

The reciprocals of these propositions are also true.

If a line be parallel to one of the planes of projection, its projection upon the other plane will be parallel to the ground-line. Thus, for example, if a line be parallel to a horizontal plane, its vertical projection will be parallel to the ground-line; and if it is parallel to the vertical plane, its horizontal projection will be parallel to the ground-line.

Reciprocally, if one of the projections of a line be parallel to the ground-line, this line will be parallel to the plane of the other projection. Thus, for example, if the vertical projection of a line be parallel to the ground-line, this line will be parallel to the horizontal plane, and *vice versâ*.

If a line be at any time parallel to the two planes of projection, the two projections of this line will be parallel to the ground-line; and reciprocally, if the two projections of a line be parallel to the ground-line, the line itself will be at the same time parallel to the two planes of projection.

If a line be perpendicular to one of the planes of projection, its projection upon this plane will only be a point, and its projection upon the other plane will be perpendicular to the ground-line. Thus, for example, if the line in question be perpendicular to the horizontal plane, its horizontal projection will be only a point, and its vertical projection will be perpendicular to the ground-line.

Reciprocally, if one of the projections of a straight line be a point, and the projection of the other perpendicular to the ground-line, this line will be perpendicular to the plane of projection upon which its projection is a point. Thus the line will be perpendicular to the horizontal plane, if its projection be the given point in the horizontal plane.

If a line be perpendicular to the ground-line, the two projections will also be perpendicular to this line. The reciprocal is not true; that is to say, that the two projections of a line may be perpendicular to the ground-line, without having the same line perpendicular to the ground-line.

If a line be situated in one of the planes of projection, its projection upon the other will be upon the ground-line. Thus, if a line be situated upon a horizontal plane, its vertical projection will be upon the ground-line; and if this line were given upon the vertical plane, its horizontal projection would be upon the ground-line.

Reciprocally, if one of the projections of a line be upon the ground-line, this line will be upon the plane of the other projection. Thus, for example, if it be the vertical projection of the line in question which is upon the ground, this line will be upon the horizontal plane; if, on the contrary, it were upon the horizontal projection of this line which was upon the ground-line, this line would be upon the vertical plane.

If a line be at any time upon the two planes of projection, the two projections of this line would be upon the ground-line, and the line in question would coincide with this ground-line. Reciprocally, if the two projections of a line were upon the ground-line, the line itself would be upon the ground-line.

If two lines in space are parallel, their projections upon each plane of projection are also parallel. Reciprocally, if the projections of two lines are parallel on each plane of projection, the two lines will be parallel to one another in space.

If any two lines whatever in space cut each other, the projections of their point of intersection will be upon the same perpendicular line to the ground-line, and upon the points of intersection of the projections of these lines. Reciprocally, if the projections of any two lines whatever cut each other in the two planes of projection, in such a manner that their points of intersection are upon the same perpendicular to the ground-line, these two lines in question will cut each other in space.

The position of a plane is determined in space, when we know the intersections of this plane with the planes of projection.

The intersections A B, A C, of the plane in question, with the planes of projection, are called the *traces* of this plane.

The trace situated in the horizontal plane is called the *horizontal trace*, and the trace situated in the vertical plane is called the *vertical trace*.

A very important remark is, that the two traces of a plane intersect each other upon the ground-line.

If a plane be parallel to one of the planes of projection, this plane will have only one trace, which will be parallel to the ground-line, and situated in the other plane of projection. Reciprocally, if a plane has a trace parallel to the ground-line, this plane will be parallel to the plane of projection which does not contain this trace. Thus: —

1st. If a plane be parallel to the horizontal plane, this plane will not have a horizontal trace, and its vertical trace will be parallel to the ground-line. Likewise, if a plane be parallel to the vertical plane, this plane will not have a vertical trace, and its horizontal trace will be parallel to the ground-line.

2d. If a plane has only one trace, and this trace parallel to the ground-line, let it be in the vertical plane; then the plane will be parallel to the horizontal plane. So if the trace of the plane be in the horizontal plane, and parallel to the ground-line, the plane will be parallel to the vertical plane.

If one of the traces of a plane be perpendicular to the ground-line, and the other trace in any position whatever, this plane will be perpendicular to the plane of projection in which the second trace is. Thus, if it be a horizontal trace which is perpendicular to the ground-line, the plane will be perpendicular to the vertical plane of projection; and if, on the contrary, the vertical trace be that which is perpendicular to the ground-line, then the plane will be perpendicular to the horizontal plane.

Reciprocally, if a plane be perpendicular to one of the planes of projection without being parallel to the other, its trace upon the plane of projection to which it is perpendicular will be to any position whatever, and the other trace will be perpendicular to the ground-line. Thus, for example, if the plane be perpendicular to the vertical plane, the vertical trace will be in any position whatever, and its horizontal trace will be perpendicular to the ground-line. The reverse will also be true, if the plane be perpendicular to the horizontal plane.

If a plane be perpendicular to the two planes of projection, its two traces will be perpendicular to the ground-line. Reciprocally, if the two traces of a plane are in the same straight line perpendicular to the ground-line, this plane will be perpendicular to both the planes of projection.

If the two traces of a plane are parallel to the ground-line, this plane will be also parallel to the ground-line. Reciprocally, if a plane be parallel to the ground-line, its two traces will be parallel to the ground-line.

When a plane is not parallel to either of the planes of projection, and one of its traces is parallel to the ground-line, the other trace is also necessarily parallel to the ground-line.

If two planes are parallel, their traces in each of the planes of projection will also be parallel. Reciprocally, if on each plane of projection the traces of the two planes are parallel, the planes will also be parallel.

If a line be perpendicular to a plane, the projections of this line will be in each plane of projection perpendicular to the respective traces in this plane. Reciprocally, if the projections of a line are respectively perpendicular to the traces of a plane, the line will be perpendicular to the plane.

If a line be situated in a given plane by its traces, this line can only intersect the planes of projection upon the traces of the plane which contains it. Moreover, the line in question can only meet the plane of projection in its own projection. Whence it follows, that the points of meeting of the right line and the planes of projection are respectively upon the intersections of this right line and the traces of the plane which contains it.

If a right line, situated in a given plane by its traces, is parallel to the horizontal plane, its horizontal projection will be parallel to the horizontal trace of the given plane, and its vertical projection will be parallel to the ground-line. Likewise, if the right line situated in a given plane by its traces is parallel to the vertical plane, its vertical projection will be parallel to the vertical line of the plane which contains it, and its horizontal projection will be parallel to the ground-line.

Reciprocally, if a line be situated in a given plane by its traces, and, for example, let its horizontal projection be parallel to the horizontal trace of the given plane, this line will be parallel to the horizontal plane, and its vertical projection will be parallel to the ground-line. Likewise, if the vertical projection of the line in question be parallel to the vertical trace of the given plane, this line will be parallel to the vertical plane, and its horizontal projection will be parallel to the ground-line.

## SECTION IV. — On the Developments of the Surfaces of Solids.

### PROBLEM I.

To find the development of the surface of a right semi-cylinder.

*Plate* IV., *fig.* 7. Let A C D E be the plane passing through the axis. On A C, as a diameter, describe the semicircular arc A B C. Produce C A to F, and make A F equal to the development of the arc A B C. Draw F G parallel to A E, and E G parallel to A F; then A F G E is the development required.

### PROBLEM II.

To find the development of that part of a semi-cylinder contained between two perpendicular surfaces.

*Figs.* 8, 9, and 10. Let A C D E be a portion of a plane passing through the axis of the cylinder, C D and A E being sections of the surface, and let D E and G F be the insisting lines of the perpendicular surface; also let A C be perpendicular to A E and C D. On A C, as a diameter, describe the semicircular arc A B C. Produce C A to H, and make A H equal to the development of the arc A B C. Divide the arc A B C, and its development, each into the same number of equal parts at the points 1, 2, 3.

Through the points 1, 2, 3, &c., in the semicircular arc and in its development, draw straight lines parallel to A E, and let the parallel lines through 1, 2, 3, in the arc A B C, meet F G in *p*, *q*, *r*, &c., and A C in *k*, *l*, *m*, &c. Transfer the distances *k p*, *l q*, *m r*, &c., to the development upon the lines 1 *a*, 2 *b*, 3 *c*, &c. Through the points F, *a*, *b*, *c*, &c., draw the curve line F *c* I. In the same manner draw the curve line E K; then F E K I will be the development required.

### PROBLEM III.

To find the development of the half surface of a right cone, terminated by a plane passing through the axis.

*Fig.* 11. Let A C E be the section of the cone passing along the axis A E; and C E the straight lines which terminate the conic surface, or the two lines which are common to the section C A E and the conic surface; and let A C be the line of common section of the axal plane, and the base of the cone.

On A C, as a diameter, describe a semicircle A B C. From E, with the radius E A, describe the arc A F, and make the arc A F equal to the semicircular arc A B C, and join E F; then the sector A E F is the development of the portion of the conic surface required.

### PROBLEM IV.

To find the development of that portion of a conic surface contained by a plane passing along the axis, and two surfaces perpendicular to that plane.

*Fig.* 12. Let A C E be the section of the cone along the axis, and let A C and G I be the insisting lines of the perpendicular surfaces. Find the development A E F as in the preceding problem. Divide the semicircular arc A B C, and the sectorial arc A F, each into the same number of equal parts, at the points 1, 2, 3, &c. From the points 1, 2, 3, &c., in the semicircular arc, draw straight lines 1 *k*, 2 *l*, 3 *m*, &c., perpendicular to A C. From the points *k*, *l*, *m*, &c., draw straight lines *k* E, *l* E, *m* E, &c., intersecting the curve A C in *p*, *q*, *r*, &c. Draw the straight lines *p t*, *q u*, *r v*, &c., parallel to one side, E C meeting A C in the points *t*, *u*, *v*, &c. Also from the points 1, 2, 3, in the sectorial arc A F, draw the straight lines 1 E, 2 E, 3 E, &c. Transfer the distances *p t*, *q u*, *r v*, &c., to 1 *a*, 2 *b*, 3 *c*, &c.; then through the points A, *a*, *b*, *c*, &c., draw the curve A *c* F, and A *c* F is one of the edges of the development, and by drawing the other edge, the entire development A G H F will be found.

## SECTION V. — Construction of the Moulds for Horizontal Cylindretic Vaults, either terminating Rightly or Obliquely, upon Plane or Cylindrical Walls, with the Joints of the Courses either in the Direction of the Vault, perpendicular to the Faces, or in Spiral Courses.

### DEFINITIONS OF MASONRY, WALLS, VAULTS, &c.

Stone-cutting is the art of reducing stones to such forms that when united ogether they shall form a determinate whole.

In preparing stones for walls, of which their surfaces are intended to be perpendicular to the horizon, nothing more is necessary than to reduce the stone to its dimensions, so that each of its eight solid angles may be contained by three plane right angles.

Moreover, in working the stones of common straight right cylindretic vaults, where the planes of the sides of the joints terminate upon the intrados or extrados of the arch or vault, in straight parallel ruled lines of the cylindretic surface, there can be no difficulty; for if one of the beds of the stone be formed to a plane surface, and if this side be figured to the mould, and the opposite ends squared, and, lastly, the face or vertical moulds applied upon the ends thus squared, and their figures drawn, these figures will be the two ends of a prism, consisting of equal and similar figures, and will be similarly situated; and therefore we have only to form this prism, in order to form the arch-stone required.

But the formation of the stones in the angles of vaults, and in the courses of spherical niches and domes, are much more difficult, and require more consideration. In such constructions various methods may be employed, and some of these, in particular instances, with great advantage, both in the saving of workmanship and material, as we shall have occasion to show. In general, however, previous to the reducing of a stone to its ultimate form for such a situation, it will be found convenient to reduce the stone to such a figure as will include the more complex figure of the stone required, so that any surface of the preparatory figure may either include a surface or arris of the stone required to be formed, or be a tangent to this surface.

Surfaces are brought to form by means of straight and curved edges, always applied in a plane perpendicular to the arris-lines, so that, when a surface is thoroughly formed, the edge of application may have all its points in contact with the surface in its whole intended breadth.

A wall, in masonry, is a mass of stones or other material, either joined together with or without cement, so as to have its surfaces such that a plumb-line, descending from any point in either face, will not fall without the solid.

One of the faces of a wall is generally regulated by the other, and the regulating surface is called the principal face.

The line of intersection of the principal face of a wall and a horizontal plane on a level with the ground, or as nearly so as circumstances will permit, is called *the base-line*.

A horizontal section of a wall, through the base-line, is called *the seat of the wall*.

The other side of the seat of a wall, opposite to the base-line, is called *the rear-line*.

In exterior walls the outer surface is always the principal face, and the base and rear-lines are generally so situated, that normals drawn to the base-line, between the base and rear-lines, are all equal to one another. This uniformity most frequently takes place also in partition or division walls; but, in some instances, on account of a room being circular or elliptical, while the other faces are plane or curved surfaces, this equality of the normals cannot subsist.

If a wall be cut by a plane perpendicular to the base-line, or if the base-line be a curve perpendicular to a tangent through the point of contact, such a section is called *a right section*.

Hence, according to this definition, since the base-line is always in a horizontal plane, every straight line and every tangent to a base-line, when it is a curve, will be a horizontal line, therefore the right section must be in a vertical plane.

Walls are denominated according to the figure of their base-line. When the base-line is straight, the wall is said to be straight. Hence, if the figure of the base be an arc or the whole circumference of a circle, or a portion or the entire curve of an ellipse, the wall is said to be circular or elliptical. Other forms seldom occur in building.

Walls are more strictly defined by the joint consideration of the figures of their bases and right section.

When the base and the right section of a wall are each a straight line, and all the horizontal sections straight lines, the face of the wall is called a ruler surface, and if all the right sections have the same inclination, the wall is called a straight inclined wall; if they are all vertical, the wall is called an erect straight wall, or a vertical straight wall. If the right sections vary their inclination, the wall is called *a winding wall*.

When the base-line is the circumference or any arc of a circle, and the right section a straight line perpendicular to the horizon, the wall is said to be cylindric. If the right sections of a wall be all equally inclined to the horizon, the wall is said to be conic; and thus a wall takes also the name by which its surface is called; hence a straight wall, which has its right sections either vertical or at the same inclination, is called *a plane wall*.

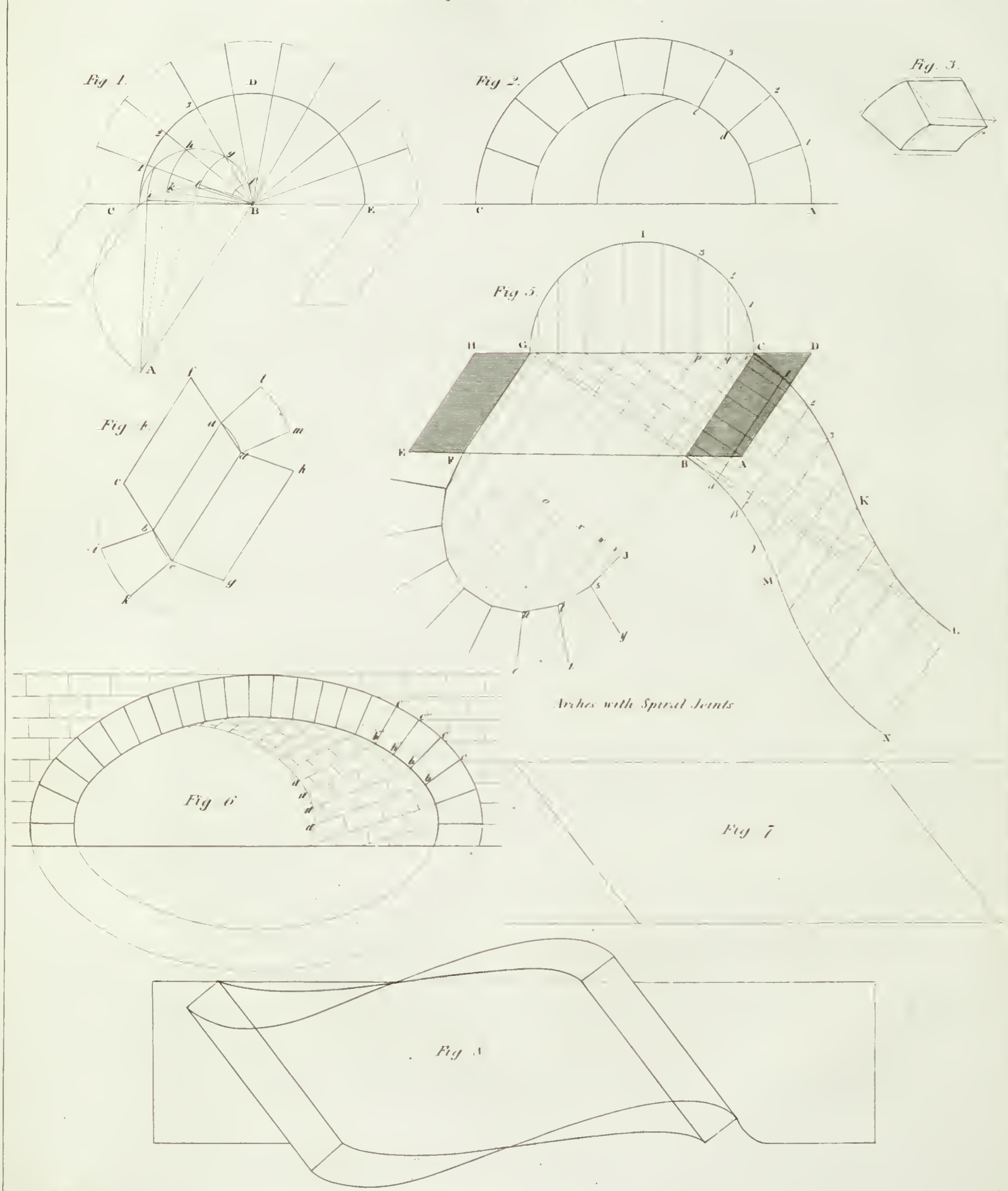
A wall in tallus, or *a battering wall*, is that of which the vertical section of the principal face is a straight line not perpendicular to the horizon. This vertical section is called *the tallus-line*.

The horizontal distance between the foot of the tallus-line and the plumb-line, passing through its upper extremity, is called *the quantity of batter;* and the plumb-line, from the top of the tallus-line to the level of its foot, is called *the vertical of the batter*.

The interstices between the stones, for the insertion of cement or mortar, in

Pl 5.

# OBLIQUE ARCHES

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order to connect the stones into one solid mass, are called *joints*, and the surfaces of the stones between which the mortar is inserted are called *the sides of the joints*.

When the sides of the joints are everywhere perpendicular to the face of a wall, and terminate in horizontal planes upon that face, such joints are called *coursing-joints;* and the row of stones between every two coursing-joints is called *a course of stones*.

An *arch* or *vault*, in masonry, is a mass of stones suspended over a hollow, and supported by one or more walls at its extremities, the surface opposed to the hollow being concave, and such that a vertical line, descending from any point in the curved surface, may not meet the curved surface in another point.

The concave surface under the arch or vault is called *the intrados* of that arch or vault; and if the upper surface be convex, this convex surface is called *the extrados*.

Those joints which terminate upon the intrados in horizontal lines are called *coursing-joints*, and the coursing-joints will either be straight, circular, or elliptic, according as the horizontal sections of the intrados are straight, circular, or elliptic.

Whether in walling or in vaulting, the joints of the stones should always be perpendicular to the face of the wall, or to the intrados of the arch, and the joints between the stones should either be in planes perpendicular to the horizon, or in surfaces which terminate upon the face of the wall or intrados of a vault in horizontal planes; these positions being necessary to the strength, solidity, and durability of the work.

Walls and vaults being of various forms, namely, straight, circular, and elliptic, depending on the plan of the work; hence the construction will depend upon the simple figure or upon the complex figure when combined in two.

## SECTION VI. — On Oblique Arches.

### PROBLEM I.

To execute an oblique cylindroidic arch, intersecting each side of the wall in a semicircle, the imposts of the arch being given.

Let *fig.* 2, *Plate* V., be the elevation, and in *fig.* 5, let A B C D, E F G H, be the two imposts which are equal and similar parallelograms, having the sides A B, F E, one of each in a straight line, and the sides D C and G H in a straight line.

Join G C, and on G C, as a diameter, describe the semicircle G I C, which, if conceived to be turned upon the line G C as an axis, until its plane become perpendicular to the seat B C G F of the soffit of the arch, it will be placed in its due position. Divide the semicircular arc C I G into as many equal parts as the ring-stones are to be in number. We shall here suppose there are to be nine ring-stones. From the points of division 1, 2, 3, &c., draw ordinates perpendicular to G C, meeting G C in the points $p, q, r$, &c. Perpendicular to C B, the jamb-line of the impost, draw the lines $p$ 1, $q$ 2, $r$ 3, &c.; from the point C as a centre, with the chord of one ninth part of the semicircular arc, C I G′, describe an arc intersecting $p$ 1 C B at 1; from the point 1, with the same radius, describe an arc intersecting the line $q$ 2 in the point 2; from the point 2, as a centre, with the same radius, describe an arc intersecting the line $r$ 3 in the point 3; and so on. Join the point C and 1; 1 and 2; 2 and 3, &c., and thus form the entire edge C K L of the development of the semicircular arc C I G.

Through the points 1, 2, 3, &c., in C K L, draw the lines 1 $\beta$, 2 $\gamma$, 3 $\delta$, &c., parallel to C B, and make 1 $\beta$, 2 $\gamma$, 3 $\delta$, &c., each equal to C B; and join B $\beta$, $\beta\,\gamma$, $\gamma\,\delta$, &c.; then C B $\beta$ 1 is the soffit of the first ring-stone; 1 $\beta\,\gamma$ 2 is the soffit of the second ring-stone; 2 $\gamma\,\delta$ 3, the soffit of the third ring-stone; and so on.

Perpendicular to G F draw F J; produce C B to J; and, parallel to C J, draw $p\,s$, $q\,t$, $r\,u$, &c. Intersecting F J in the points $v$, $w$, $x$, &c., make $v\,s$, $w\,t$, $x\,u$, &c., respectively equal to $p$ 1, $q$ 2, $r$ 3, &c. Join J and $s$, $s$ and $t$, $t$ and $u$, &c.; and complete the polygonal line J $u$ F. Through the points $s$, $t$, $u$, &c., draw the joint lines $s\,y$, $t\,z$, $u\,\Theta$, radiating to the point $o$; then will the angles of inclination of the beds and soffits be N J $s$, $y\,s$ J, the first ring-stone; $y\,s\,t$, $z\,t\,s$, for the second ring-stone; $z\,t\,u$, $\Theta\,u\,t$, for the third ring-stone; and so on.

From any point B in E C, *fig.* 1, make the angle C B A equal to the angle A B C of the impost, *fig.* 5. Prolong C B to E. From B as a centre, with any radius, describe the semicircular arc C D E; and on B C as a diameter, describe another semicircular arc C $g$ B. Divide the semicircular arc C D E, in the points 1, 2, 3, &c., into nine equal parts, equal to the number of ring-stones, and draw the radials 1 B, 2 B, 3 B, &c., intersecting the semicircular arc C $g$ B in the points $f$, $g$, $h$, &c. Draw C A perpendicular to B C; and in B A, as a diameter, describe the semicircular arc B C A. From the point B, with the radii B $f$, B $g$, B $h$, &c., describe the arcs $f\,i$, $g\,k$, $h\,l$, &c., meeting the semicircular arc B C A in the points $i$, $k$, $l$, &c., and draw the straight lines B $i$, B $k$, B $l$, &c. Then, A B C being the angle of the impost, A B $i$ will be the angle of the joints at the junction of the first and second ring-stones; A B $k$ the angle of the joints at the junction of the second and third ring-stones; A B $l$ will be the angle of the joints at the junction of the third and fourth ring-stones, &c.

To apply the moulds for cutting any one of the ring-stones, or to form the solid angles made by the face, the two beds, and the soffit of the stone, which being done will form that ring-stone. — For instance, let it be required to form the third ring-stone: — We have given the plane angle $2\,\gamma\,\delta$, *fig.* 2, which is a side, and the plane angle A B *k*, *fig.* 1, another adjacent side; also the angle *z t u*, *fig.* 5, which is the inclination of these two sides, to construct the solid angle. This can be easily done by working the bed of the stone corresponding to the joint $2\,\gamma$ on the soffit, *fig.* 5; then work the narrow side of the stone, from which the soffit is to be formed, first as a plane surface, making an angle *z t u* with the bed first wrought; place the surface of the mould *a b c d*, *fig.* 4, upon the narrow side of the stone which is to form the soffit, so that the edge *a b* may be upon the arris of the stone; then, by the edge *b c*, draw a line; again, upon the wrought side which is intended for the bed apply the angle A B *k*, *fig.* 1, so that the line A B may be upon the arris, and the point B on the same point that *b* was applied; then by the leg B *k*, which is supposed to be upon the surface of the bed, draw a line; we have only to cut away the superfluous stone on the outside of the two lines on the bed and on the soffit; and thus we shall form a complete trehedral; the plane soffit of the stone being gauged to its breadth, and the mould 2 *e d* 3, *fig.* 2, being applied upon the last wrought side, so that the points *d*, *e*, may be upon the points of the stone to which *b* and *c* were applied; then, drawing a line by the edge *d* 3, and cutting away the superfluous stone between the two lines on the front, and on the plane of the soffit, will form the upper bed of the stone.

This will be made sufficiently evident by a development of the soffit, the two beds, and the front of the ring-stone. Make an equal and similar parallelogram *a b c d*, *fig.* 4, to that of $2\,\gamma\,\delta\,3$, *fig.* 5. Make the angles *a b e*, *d c g*, *fig.* 4, respectively equal to the angles A B *k*, A B *l*, *fig.* 1; then *b c* being equal to *d e*, *fig.* 2, apply the mould 2 *d e* 3 so that the points *d*, *e*, may be upon *b c*, *fig.* 4, and draw the front of the stone *b c k i*, *fig.* 4, and similarly draw *a d m l*. Make *b e* equal to *b i*, *c g* equal to *c k*, and draw *e f* and *g h* parallel to *b a* or *c d*, and this will complete the development.

A complete model of the stone will instantly be formed, by revolving the four sides *a b e f*, *b c k i*, *c d h g*, *d a l m*, upon the four lines *b a*, *b c*, *c d*, *d a*, as axes, until *e* coincide with *i*, *k* with *g*, *h* with *m*, and *l* with *f*.

We have here made use of the development of the intrados in the construction of the solid angles, as being easily comprehended. The ring-stones might, however, have been formed by the angle of the joints, which is one side of a trehedral; one of the angles of the face mould, which is the other adjacent side; and the inclination of these two sides; so that we shall have here also two sides and the contained angle, to construct the solid angle of the trehedral. As an example, let it again be required to construct the third ring-stone. To find the angle which the face of the third ring-stone makes with the bed in the second joint:—We have here given the two legs A B C, C B 2, *fig.* 1, of a right-angled trehedral, to find the angle which the hypothenuse makes with the side C B 2; this being found, will be the inclination of the face-mould 2 *d e* 3, *fig.* 2, and A B *k*, *fig.* 1. Therefore, in this case, work the bed of the stone first, then the face, to the angle of inclination thus found. Upon the arris apply the leg A B of the joint mould A B *k*, *fig.* 1, so that the side B *k* may be upon the bed, and draw a straight line on the bed by the edge B *k;* next apply the mould 2 *d e* 3, so that the arc *d* 2 may be upon the arris, and the point *d* upon the same point of the arris to which the point B was applied, and the chord *d e* upon the face; then draw a line on the face of the stone, by the leg *d e;* and work off the superfluous stone; and the face will be exhibited. *Fig.* 3 shows the stone as wrought.

From what has been said, it is evident that if one of the solid angles of a ring-stone be formed of an oblique arch in a straight wall, the remaining solid angle may be formed without the use of the trehedral. Thus, for instance, suppose the solid angle which is formed be made by the surface of the soffit, the bed, and the face of the arch:—we have only to gauge the soffit to its breadth, and apply the head-mould upon the face of the stone; then, by working off the superfluous stone between these lines, another solid angle will be formed by the surface of the soffit, the upper bed of the stone, and the face of the arch.

And since the angle of the joints is the same in the lower and upper beds of any two ring-stones that come in contact with each other, the same angle of the joints will do for both, so that, in fact, if this be carried from one ring-stone to another, the arch may be executed without any joint mould.

This mode would, however, not only be inconvenient, but liable to very great inaccuracy. It would be inconvenient, as it is necessary to work one stone before another, so that only one workman could be employed in the construction of the arch. It would be liable to inaccuracy when the number of ring-stones are many, for then any small error would be liable to be multiplied or transmitted from one stone to another. Besides, it is satisfactory to have a mould to apply, in order to examine the work in its progress.

What has been now observed, with regard to the oblique arch in a straight wall, and with respect to the angle on the edges of the point, will apply to every arch of which the intrados is a cylindric or cylindroidic surface.

In the construction of any object, it is always desirable to have two different methods, as one may always be a proof or check to the other. Besides, though these methods may be equally true in principle, one of them may be often liable to greater inaccuracy in its construction than the other.

PROBLEM II.

To construct the moulds for a cylindretic oblique arch terminating upon the face of a wall in a plane at oblique angles to the springing plane of the vault, so that the coursing-joints may be in planes parallel to the ruler lines of the intrados of the vault.

Let the vertical plane of projection be perpendicular to the axis of the intrados, and it will therefore be also perpendicular to all the joints of which their planes are parallel to the axis: hence, —

The vertical projection of the intrados will be a curve equal and similar to the curve of the right section of the intrados.

The vertical projections of the coursing-joints will be radiant straight lines, intersecting the curve-lined projection of the intrados.

The vertical projections of all the joints which are in vertical planes parallel to the axis will be straight lines perpendicular to the ground-line.

The vertical projection of all the joints *m*, horizontal planes, will be straight lines parallel to the ground-line.

Moreover, the vertical projections of the intersections of planes which are parallel to the axis will be points.

The horizontal projections of the planes of the coursing-joints, and of all the intersections of the planes of all joints which are parallel to the axis, will be straight lines perpendicular to the ground-line.

And because the axis of the archant is perpendicular to the vertical plane, the vertical projections of the intrados, and of the joints which are parallel to the axis, will have the same position to one another, as the curve and other lines in the right section which are formed by the joints in planes parallel to the axis.

All sections which are perpendicular to the horizon will have straight lines for their horizontal projections.

The length of any inclined line will be to the length of its projection, as the radius is to the cosine of the line's inclination to the plane of projection.

We shall suppose that the stones which constitute the intrados of the archant have not fewer than three, nor more than four, of their faces that intersect the intrados. The stones which form the face of the archant, when they do not reach the rear of the vault, have three of their faces which intersect the intrados, and three at least which intersect the face.

We shall call all these surfaces, which intersect the intrados or face of the archant, *the retreating sides of joints of the stones ;* and the surface of any stone which forms a part of the intrados, *the douelle of the stone.*

When the stones do not reach from the front to the rear of the intrados of an archant, they are arranged in rows, in such a manner, that the stones which constitute any one of the rows have as many of their retreating sides as there are stones in the row in one continued surface, and the opposite retreating sides of all the stones in another continued surface, while the heads form a portion of the intrados extending from front to rear of the vault, and the remaining retreating sides of the stones either come in contact, or are connected together by mortar.

Every such row of stones is called *a course of vaulting.*

One course may be joined to another by bringing their adjacent continued surfaces in contact; but they are generally cemented with mortar, which is called *the coursing-joint,* and as this cementing substance should be as thin as possible, and of an equal thickness, we shall suppose that the coursing-joints intersect the intrados in lines extending from front to rear of the vault, and we shall call these lines *the coursing lines of the intrados.*

In this example, as the vertical projection of the intrados, and of the joints which are in planes parallel to the axis, are identical in all respects to the lines of the right section, the dimensions between every two corresponding points being equal in both, we may therefore substitute at once the right section for the vertical projection, placing the right section upon the ground-line U V.

*Plate* XI. Let No. 1 be the right section placed in the situation of the vertical plane projection upon the ground-line U V, the curve line C O C′ being the vertical projection of the intrados, A D, B F, C H, the projections of the vertical projection coursing-joints, meeting the projection of the intrados in the points A, B, C. Of these radiant lines C H is the projection of the springing. The line B F meets the line F G parallel, and E F perpendicular, to the ground-line U V. The extrados Z E D Y of this section is a straight line parallel to the ground-line. As this right section of this vault is symmetrical, we shall only describe one half; the other will be understood by the same rules.

Let *r s*, No. 2, be the trace of the vertical face of the wall on the horizontal plane of projection, making a given angle with the ground-line U V, and let *u v* and *r s* be the traces of the inclined face of the wall; the inclination of this face being given by a right section of the wall.

Let $\Gamma \Delta \Lambda \Pi$, No. 3, be the right section of the wall, of which $\Lambda \Pi$, the base, is equal to the shortest distance between the two traces *u v* and *r s*, No. 2, of the faces of the wall. The line $\Pi \Gamma$ of this section is the section of the vertical face, and $\Lambda \Delta$ that of the inclined face of the wall.

This section $\Gamma A \Delta \Pi$, No. 3, is so situated, that the base line $\Delta \Pi$ is perpendicular to the traces *u v*, *r s*, of the faces of the wall, No. 2, the point $\Pi$ being in the line *r s*, or *s r* prolonged, therefore the point $\Delta$ in the line *u v*, or *v u* prolonged, and $\Pi \Gamma'$ being perpendicular to $\Delta \Pi$ will be in the same straight line with the horizontal trace *r s* of the vertical face of the wall.

In order to obtain the projection of the intersection of the intrados and of the joints which are in planes parallel to the axis of the intrados with the inclined face of the wall, we must find the projection of every line in this inclined face made by the intersection of a horizontal plane passing through every point in the right section which is formed by every two lines in its construction.

For this purpose it will be necessary to find the horizontal projection of every point of the lines where the intersections of the planes parallel to the axis meet the inclined face of the wall. To proceed: —

Take all the heights of the points of the right section, and apply them respectively from the point $\Pi$ in the line $\Pi \Gamma$, No. 3; through these points draw lines parallel to $\Delta \Pi$, so that each line may meet the sloping line $A \Delta$. From each of the points in the line $A \Delta$ draw lines parallel to the horizontal trace *u v*, No. 2, and lines being drawn from the corresponding points of the right section will give the points required by the intersection of the two systems of parallel lines.

Thus, to find the horizontal projection of the intersection of any particular line which is parallel to the axis with the inclined face of the wall, this line being given by its intersecting point in the right section, No. 1; this point being the intersection of one of the coursing lines, namely, the first A from the middle of the section No. 1.

Draw A *a* perpendicular to the ground-line, and transfer the height K A of the point A, No. 1, upon the line $\Pi \Gamma$, No. 3, from $\Pi$ to 1. Draw 1-2 parallel to $\Pi \Delta$, $A \Delta$ meeting P Q in 2. From 2 draw 2 *a* parallel to either of the horizontal traces *u v*, or *r s*, No. 2, and the point *a* (No. 2) is the horizontal projection of the extremity of the coursing line of the intrados which passes through the point A of the right section.

In the same manner may be found the projections *b* and *c* of the intersections of the coursing-joints of the intrados, with the face of the archant, and also those of the intersections of the planes parallel to the axis; the projections of these points being exhibited by Italic letters corresponding to those of the Roman in the right section.

To find the development of the intrados or soffit of the arch.

Parallel to the ground-line in No. 2, draw the regulating line $\delta \varepsilon$ in the horizontal plane of projection, intersecting the projections $a a'$, $b b'$, $c c'$, &c. of the coursing-joint lines in the points $\alpha$, $\beta$, $\gamma$, &c.

In any convenient situation, No. 4, draw the line V W, and in V W take any convenient point $o$. In $o$ V make $o\,a$ equal to O A, No. 1, the half-chord of the arc of the section of the key-course; and in No. 4, make $a\beta$, $\beta\gamma$, &c., equal to the succeeding chords A B, B C, &c., No. 1, of the sections of the courses in intrados.

Through the points $\alpha$, $\beta$, $\gamma$, No. 4, draw the lines $a a'$, $b b'$, $c c'$, perpendicular to V W, and make $a\,a$, $\beta\,b$, $\gamma\,c$, respectively equal to $a\,a$, $\beta\,b$, $\gamma\,c$, No. 2, as also $a\,a'$ $\beta\,b'$, $\gamma' c$, No. 4, equal to $a\,a'$, $\beta\,b'$, $\gamma\,c'$, No. 2. In No. 4, join $a\,b$, $b\,c$, on the one side, and $a'b'$, $b'c'$, on the other; then $a\,a'b'b$, $b\,b'c'c$, will be the chord-planes of the soffits of the courses of the stones on each side of the key-course. The figures of the chord-planes of the right-hand side of the arch being found in the same manner, will give the entire development of the intrados by joining the corresponding ends of the chord-plane of the key-course.

Through any convenient point V, No. 4, in the line V W, draw a c′ perpendicular to V W, and prolong W V to D. Make V D equal to A D, No. 1, and through D, No. 4, draw d d′ parallel to a c. In a c, No. 4, make V a, V a′, respectively equal to $a\,a$, $a\,a'$, No. 2, and make D d, D d′, No. 4, respectively equal to 1 $d$, 1 $d'$, No. 2. Join a d, a d′, then will a a′d′d, No. 4, be the side or figure of the coursing-joint corresponding with the line A D, No. 1. In the same manner the remaining figures b b′f′f, c c′h′h, will be found, as also the remaining figures of the coursing-joints on the right hand side.

Then the figures of the moulds for the course of stones, of which the right section is a figure equal and similar to A B F E D, No. 1, are No. 1, and $a\,a'b'b$, a a′d′d, b b′f′f, No. 4. All the stones are wrought to the form of right prisms before the heads in the front and rear of the arch are formed, then the moulds of the upper and lower beds are applied, and their figures are drawn upon the surfaces of the coursing-joints, so as to give the intersections of the coursing-joints with the face of the arch.

In the course of stones on the left hand, next to the key-course $a\,a'b'b$, No. 4, is the chord-figure of the intrados, a a′d′d, No. 4, the upper bed, and b b′f′f the lower bed.

To find any point in the oblique face of the arch. Let the point to be found be the point corresponding to the point A.

The place of the point A in the oblique line $\mathcal{A}\,\mathcal{A}$, No. 3, is at the point 2, and its place upon the projection No. 2 is at $a$. Draw $\mathcal{A}\,\Upsilon$ perpendicular to $\mathcal{A}\,v$, or to $u\,v$, and in $\mathcal{A}\,\Upsilon$ make $\mathcal{A}\,2$ equal to $\mathcal{A}\,2$ in $\mathcal{A}\mathcal{A}$. From the point 2, in $\mathcal{A}\,\Upsilon$,

# OBLIQUE CYLINDRIC INTRADOS

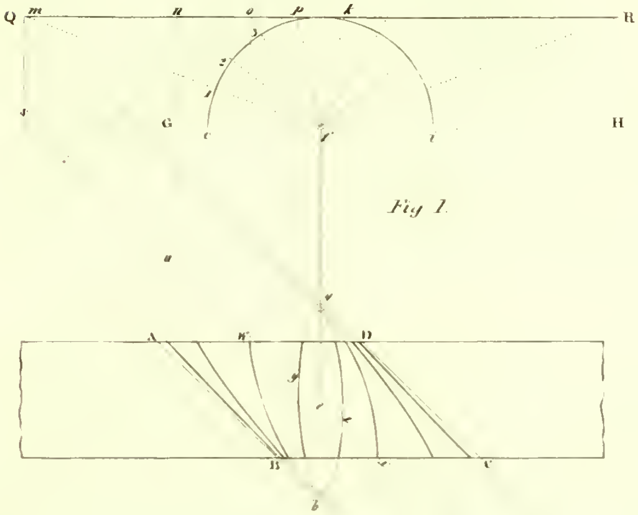



Fig 1.

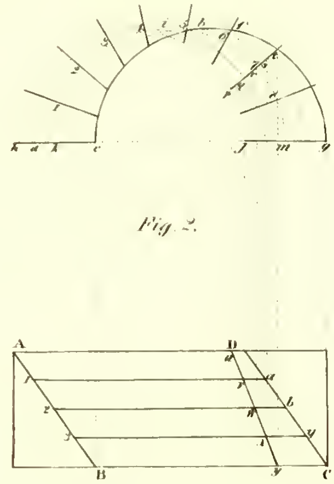



Fig. 2.

Fig. 3.

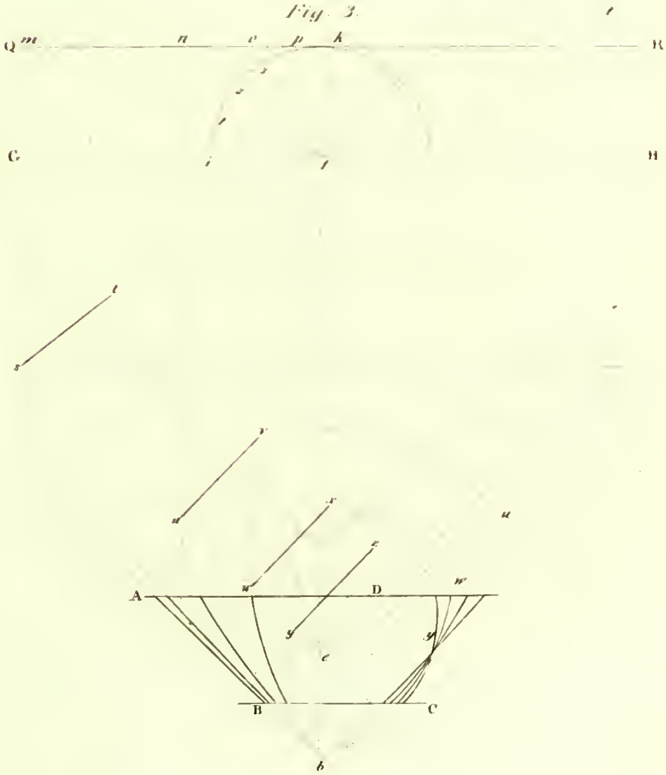
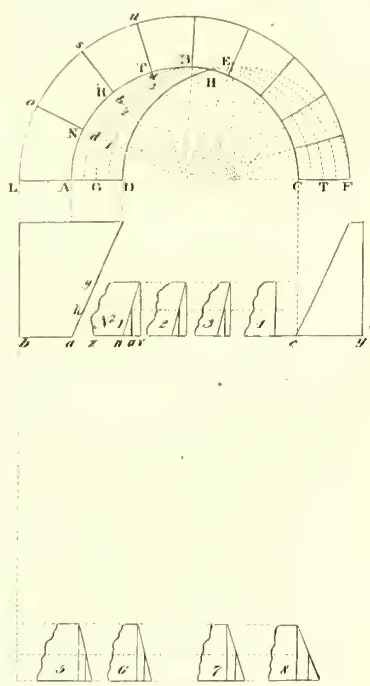



Fig. 4.



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draw $2p$ parallel to $u\,v$, and draw $a\,p$ perpendicular to $u\,v$, and the point $p$ will be in the curve of the oblique face of the arch.

In the same manner will be found the points $i$, $q$, &c., in the curve of the oblique face of the arch, as also all other points, by first finding their projections as at No. 2, and the heights of these points upon the oblique line $\mathit{\Delta\,\Delta}$, No. 3, and then transferring the points thus found upon the perpendicular $\mathit{\Delta\,\Upsilon}$. Through the points found in the perpendicular $\mathit{\Delta\,\Upsilon}$, draw lines parallel to $u\,v$, to intersect with lines drawn perpendicular to $u\,v$ from the projections of the points to be found in No. 2, and the points of intersection of every two lines will be the points in the oblique face of the arch corresponding to those in the section No. 1.

The curve thus found in the oblique face of the arch will be an oblique curve; therefore the line $u\,v$ will not be an axis, but a diameter.

To find the direction of any joint in the oblique face of the arch, the plane of the joint being perpendicular to the springing plane of the arch.

Suppose, for instance, the plane passing through L T in the elevation No. 1, perpendicular to U V. Find the projection $t$ and $l$ in the horizontal plane of projection of the points represented by T and L in the vertical plane of projection, and find the point $i$ in the curve of the oblique face of the arch, corresponding to the point T in the vertical plane of projection; then joining the points $l$ and $i$, the straight line $l\,i$ will be the position of the joint in a plane perpendicular to the springing plane of the intrados of the arch.

### PROBLEM III.

To construct an oblique arch for a canal with a cylindric intrados, so that the sides of the coursing-joints may be in planes which intersect each other in straight lines perpendicular to the two faces of the arch, and parallel to the horizon, and that the planes of the coursing-joints may make equal angles with each other: —

*Plate* VI., *fig.* 1. Let A B C D be the plane of the arch; A D and B C being the planes of the faces, and A B, D C, the planes of the springing lines of the intrados of the arch parallel to the line of direction of the canal.

Find the middle point $e$ of the parallelogram A B C D, and draw $ef$ perpendicular to A D or B C. Through any convenient point $f$ in $ef$ draw G H perpendicular to $ef$, and from the point $f$, with a radius equal to half of A D or B C, describe the semi-circumference $i\,k\,l$ meeting G H in $i$ and $l$. Divide the circumference $i\,k\,l$ from $i$ into as many equal parts as the coursing-joints are intended to be in number: for example, let it be divided into nine equal parts, $i$ 1, 1 2, 2 3, &c. Draw the tangent Q R parallel to G H, and from $f$, and through the points 1, 2

3, &c., of division, draw the straight lines $f m$, $f n$, $f o$, $f p$, &c., meeting Q R in the points $m$, $n$, $o$, $p$.

Through $e$ draw $s t$ parallel to A B or D C, and draw $m s$, $n u$, $o w$, $p y$, perpendicular to G H, meeting $s t$ in the points $s$, $u$, $w$, $y$. Make $e z$, $e x$, $e v$, $e t$, equal respectively to $e y$, $e w$, $e u$, $e t$. Prolong C D to meet $e f$ in $\gamma$, and prolong $f e$ and A B to meet each other in the point $\beta$; then with the two diameters $s t$ and $\beta \gamma$ describe the ellipse $s \beta t \gamma$, and with the two diameters $u v$ and $\beta \gamma$ describe the ellipse $u \beta v \gamma$, and so on; then the portions of these curves comprised between the lines A D and B C will be the planes of the coursing-joints.

The method which has now been shown for finding the joint lines of the intrados of the arch is quite satisfactory as to the principle, since it exhibits the planes of the complete sections of the cylinder by the cutting planes of the joints to the several angles of inclination. We shall show how the joint lines of the intrados themselves may be found, as depending upon the planes of the joints.

To find the plane curves for the joints of the intrados: —

Having found the conjugate diameter $\beta \gamma$, and the semi-conjugate $e s$, as also the semi-conjugate diameter $e u$, $e w$, $e y$, *Plate* VI., *fig.* 3, as has been shown in the immediately preceding plate, proceed in the following manner. Draw $s t$, $u v$, $w x$, $y z$, perpendicular to $e s$, and make $s t$, $u v$, $w x$, $y z$, each equal to the radius of the semicircle $i k l$. Join $e t$, $e v$, $e x$, $e z$. Draw $s s'$, $u u'$, $w w'$, $y y'$, perpendicular to $\beta \gamma$ or $\beta f$; and from the point $e$ as a centre, with the radii $e t$, $e v$, $e x$, $e z$, describe the arcs $t s'$, $v u'$, $x w'$, $z y'$. Join $e s'$, $e u'$, $e w'$, $e y'$.

With the diameters $e s'$, $e u'$, $e w'$, $e y'$, and with their common conjugate $\beta \gamma$, describe the semi-ellipsis $\beta s' \gamma$, $\beta u' \gamma$, $\beta w' \gamma$, $\beta y' \gamma$, &c., then the portions of these curves contained between the lines B C and A D will be the curve lines of the joints required.

Let A B C D, *fig.* 2, be the plane, which is a parallelogram as before. Divide A B into any number of equal parts, as, for example, into four, at the points 1, 2, 3, and draw the lines 1 $a$, 2 $\beta$, 3 $\gamma$, parallel to B C or A D, meeting D C in the points $a$, $\beta$, $\gamma$, and let $h g$ be the ground-line of the elevation; then A D, 1 $a$, 2 $\beta$, 3 $\gamma$, B C, are the planes of semicircular sections of the intrados, and are each parallel to the ground-line $h g$, the elevations of these planes will be semicircles.

These elevations being described, let $e f g$ be the elevation to the plane B C, $k l m$ the elevation to the plane 2 $\beta$ in the middle, between the planes B C and A D of the semicircular sections of the cylinder. Let $c$ be the centre of the semicircular arc $k l m$, and divide the semicircular arc $k l m$ into as many equal parts as there are intended to be courses in the arch; for example, let the number of courses be nine, and therefore the semicircular arc $k l m$ must be divided into nine equal parts, in the points 1, 2, 3, &c.

From the centre $c$, &c., and through the points of division 1, 2, 3, draw lines which will be the elevation of the joints, and let $p\,t$ be one of these lines, intersecting the five semicircles in the points $p$, $q$, $r$, $s$, $t$. Draw the lines $p\,u$, $q\,v$, $r\,w$, $s\,x$, $t\,y$, perpendicular to the ground-line $h\,g$, intersecting the planes A D, 1 $a$, 2 $\beta$, 3 $\gamma$, B C′, in the points $u$, $v$, $w$, $x$, $y$, and the line $u\,v\,w\,x\,y$ being drawn, will be the correct plane of the joint required.

In the same manner the planes of the remaining joints may be found.

Let $l\,a\,d$, *fig.* 4, be the plane of one pier, and $y\,c\,f$ the plane of the other pier, $a\,d$ and $c\,f$ being the planes or horizontal sections of the springing lines of the intrados; also, let L F be the ground-line parallel to the planes of the front and rear elevations. Describe the five semicircles in the elevation as before, A B C being that in the front, D E F that in the rear, and G H I that belonging to the middle section.

Divide the semicircular arc G H I into the number of equal parts required, and let the points of division be 1, 2, 3, &c. Through the points 1, 2, 3, &c., draw the straight lines 1 $o$, 2 $s$, 3 U, &c., radiating to the centre of the semicircular arc A B C′, intersecting the curve A B C in the points N, R, T, and the lines N O, R S, T U, will be the joint lines of the face, and will be perpendicular to the curve line A B C.

In the straight line $a\,c$, which is the plane of the face of the arc, take a part $z\,n$ for the joint in the direction N O of the elevation, and let the lines 1 N, 2 R, 3 T, intersect the semicircular arc between the parallel sections A B C and D E F in the points $\alpha, \beta, \gamma$, &c. Let the points $u$ and $v$ be in the straight line $a\,c$. Make $n\,u$ and $u\,v$ respectively equal to N $\alpha$, $\alpha$ 1, and draw $u\,w$ and $v\,x$ perpendicular to $z\,v$.

Divide $a\,d$ into as many equal parts as the thickness of the arch is divided into equal parts by the planes of the semicircular arcs which are parallel to the planes of the front and rear faces; that is, divide $a\,d$ into four equal parts, and let $a\,k$, $a\,g$, be two of those parts in succession, and draw $k\,w$ and $g\,x$ parallel to $a\,c$; then $n$, $w$, $x$, will be three points in the curve which is the intersection of the plane of the curving joint and the cylindric surface forming the intrados; and thus we might find as many points as we please, by increasing the number of equidistant sections. This gives the first joint next in succession to the springing A D.

In the same manner all the other coursing-joints will be found as at No. 2, No. 3, No. 4, &c.

Observations on the preceding methods: —

The most simple construction of an oblique arch with a cylindrical intrados is that where the sides of the coursing-joint are in plane intersecting the intrados perpendicularly in straight lines, as in the first example; but when the arch is very oblique, the coursing-joints intersect the planes of the two vertical faces in very oblique angles.

It has been shown, that when the sides of the coursing-joints are in planes perpendicular to the front and rear faces, these planes cut the intrados very obliquely, except at the middle section, or in the best method in the curve of the front and rear. It therefore appears, that in an oblique arch, in order that the surfaces of the coursing-joints may intersect both the intrados and the face of the arch perpendicularly, the sides of the coursing-joints cannot be in planes.

In order that every arch may be the strongest possible, a straight line passing through any point of the surface of a joint perpendicularly to the intrados ought to have all its intermediate points between the point through which it passes, and the intrados, in the surface of the side of the coursing-joint; and in order that the stones may be reduced to their form in the easiest manner possible, the surfaces should be uniform; and the forms of the stones should be similar solids, and the solids similarly situated.

To obtain these desirable objects will not be possible where the faces of the arch are plane surfaces; however, even in this case, the joints may be so formed by uniform helical surfaces, that they will intersect the intrados perpendicularly in every point, and the faces of the arch perpendicularly in two points of the curve.

This mode of executing a bridge renders the construction much stronger than when the joints of it are parallel to the horizon. Since, in this last case, the angles of the beds and the faces are so acute upon one side, that the points of the ring-stones are very liable to be broken, or even to be fractured in large masses.

For, though the gravitating force acts perpendicularly to the horizon; yet, notwithstanding, when one body presses upon the surface of another, the faces act upon each other in straight lines perpendicularly to their surfaces. Hence a right-angled solid will resist equally upon all points of its surface.

From this consideration, we are induced to give a preference to the construction with spiral joints, though attended with greater difficulty in the execution.

### PROBLEM IV.

To execute a bridge upon an oblique plan, with spiral joints rising nearly perpendicular to the plane of the sides.

*Fig.* 7, *Plate* V., is the plan of a bevel bridge; *fig.* 6, the elevation of the same, as the two faces of the obtuse angle are shown; the joints of the intrados descend from the face of the arch in such a manner, that supposing the lines $a\,b$

Pl 7.

## DEVELOPEMENT OF THE INTRADOS.


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$a'b'$, $a''b''$, *fig.* 6, to be the joints of the intrados, meeting the curve of the intersection of the face of the arch and intrados in the points $b$, $b'$, $b''$, &c., then the joints $b\,a$, $b'a'$, $b''a''$, &c., are as nearly perpendicular to the curve $b\,b'b''b'''$ as possible for the construction to admit of, supposing the joints to be all parallel to each other. By making the joints of the intrados all parallel to each other, all the intermediate arch-stones will have the same section when cut by a plane at right angles to the arris-line of the bed and intrados of the arch; therefore, if the intermediate arch-stones are equal in length, the upper and lower beds must be the same winding surfaces, and consequently must all coincide with each other, and all the end-joints must be equal and similar surfaces, and thus all the arch-stones may be equal and similar bodies.

The most considerable obliquity of the joints in the intrados is at those two parts of the curve where it meets the horizon. The obliquity of the intradosal joints, at the crown of the arch, is considerably less than at the horizon; but in the middle of that portion of the curve between the crown and the horizon on each side, the intradosal joints are exactly perpendicular to the horizon.

Had it not been for these deviations, the execution of this arch would have been extremely easy, and very few constructive lines would have been necessary.

This arch, however, might be executed so that all the intradosal joints would be perpendicular to the curve line of the face and intrados; but this position would have caused such a diversity in the form of the stones as to increase the labor in a very great degree, and, consequently, to render the execution very expensive; and not only so, but as the joints would have been out of a parallel, their effect would have been very unsightly. A succession of equal figures, similarly formed, has a most imposing effect on the eye of the spectator. The laws of perspective produce on the imagination a most fascinating variety, the figure only varying by imperceptible degrees, which yet in the remote parts produces a great change.

There is still another method in which the greater part of the difficulty may be removed without impairing the strength of the arch; this manner is to form the ring-stones so that the joints in the intrados may be perpendicular to the curve forming its edge; the intermediate portion of the intrados to be filled in with arch-stones, which have their soffit-joints parallel to the horizon. This disposition of the joints might not be so pleasant to the eye, but, if well executed, it could not be disagreeable.

If the ends were made to form spirals, as in *fig.* 8, and a wall erected above the arch, as this wall could only be made to coincide in three points at most with the face of the arch, no regular form of work could be introduced so as to connect the wall to the ring-stones.

in the middle, it will be necessary to show the manner of finding a tangent in the middle of the curve. For this purpose, —

Make the angle E A $k$ equal to E A F, and let the point $m$ be the middle of the curve D $m$ A. Through the point $m$ draw $p\,g$ parallel to $k$ A, and $p\,g$ will be the tangent required.

In like manner, make the angle A H $f$ equal to A H G, and let $g$ be the middle point of the curve H $g$ C; through $g$ draw $r\,s$ parallel to H $f$, and $r\,s$ will be a tangent to the curve H $g$ C.

It is here evident from the tangents, that if these two curves had intersected each other in the middle, they would have been at right angles to each other; they are, however, still the projections of two straight lines bent upon the cylindric surface.

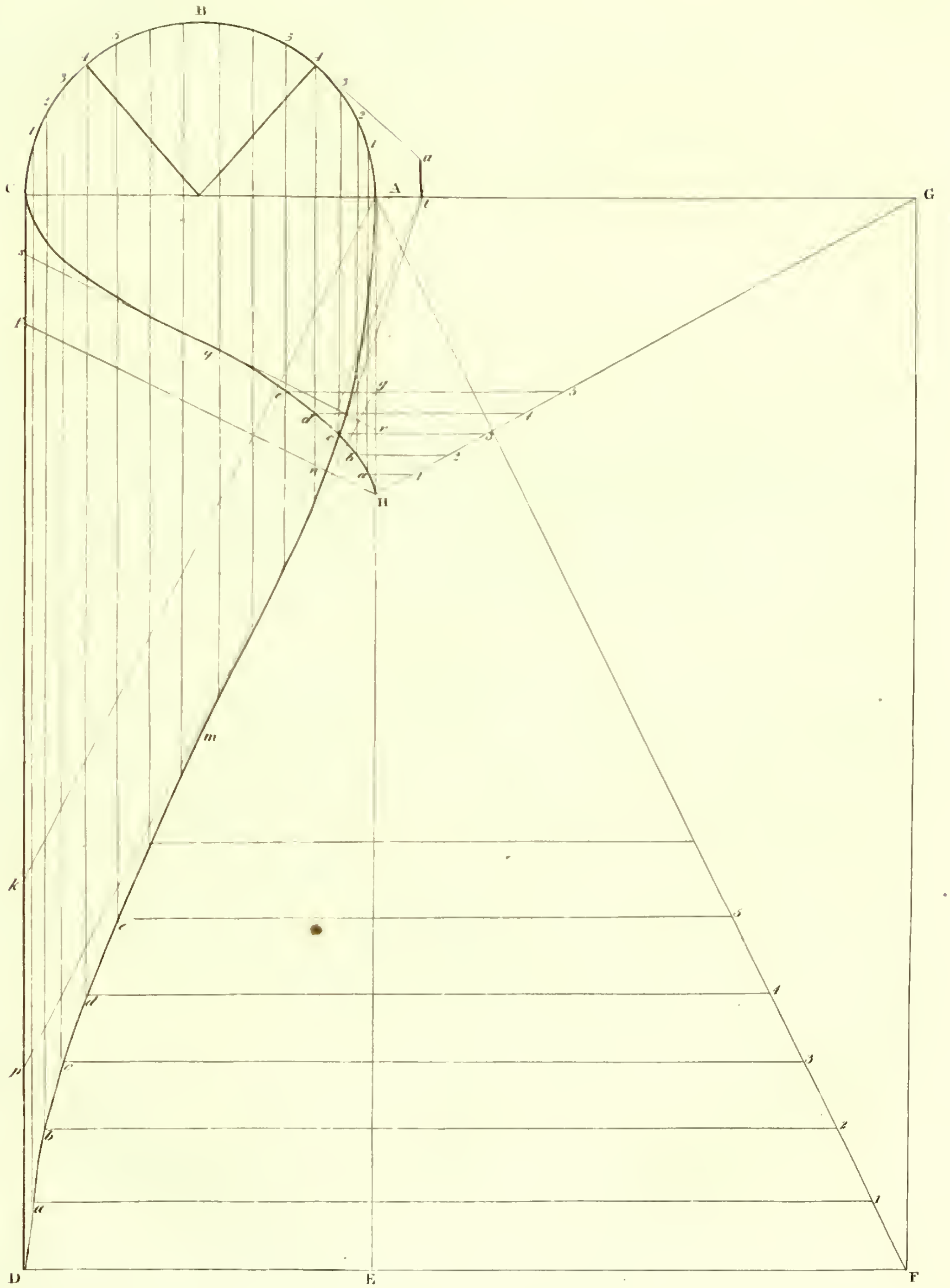
To draw a tangent to the point $n$. Draw $n$ 4 parallel to E A, meeting the curve A B in 4. Draw 4 $u$ perpendicular to the radical line, and make 4 $u$ equal to the development of the arc 4 A. Draw $u\,t$ perpendicular to A G, and join $t\,n$, which is the tangent required.

To find the curvature of a stone along the two edges of the longitudinal joints, and along the heading-joints of the intrados. In *fig.* 2, *Plate* X., which is a development of the intrados, $a\,b\,c\,d$ is the development of the intrados of an arch-stone; it is required to find the curvature along $b\,c$, and $a\,d$; also in the direction $a\,b$, $d\,c$, at the ends.

In *fig.* 1, make O A equal to the radius of the cylinder, and through A draw B E perpendicular to A O. Make the angle B O A equal to the complement of the angle with the joints in the development of the intrados made with the springing-lines, that is, equal to the angle D A E, *fig.* 2. Make O C, *fig.* 1, equal to O B, and draw O D perpendicular to B C. Make O D equal to O A. Then with the transverse axis B C, and semi-conjugate O D, describe the semi-elliptic arc or curve C D B; then the portion of the elliptic arc on each side of the point D will be the curvature in *fig.* 2, along the longitudinal edge $b\,c$ or $d\,a$ of the soffit of a stone.

Again, produce D O to E, and make O E equal to O D. In O B, take O G, equal to O A, the radius of the circular end of the cylinder; then with the transverse axis D E, and the semi-conjugate O G, describe the semi-elliptic arc D G E, and the small portion of this arc on each side of the point G has the same curvature as $a\,b$ or $d\,c$, *fig.* 2. Therefore the stone being wrought hollow, as directed in the description of the preceding plate, then the mould shown at D is that for working the longitudinal joints, or those which terminate on the soffit in the lines $a\,d$ and $b\,c$. In like manner, the mould G is that for working the heading-joints which terminate upon the soffit in the lines $a\,b$, $d\,c$, &c. It will hardly be neces-

# CYLINDRIC SECTION.

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sary to remind the reader, that the convex edge of the squares at D and G is to be applied upon the hollow soffit already wrought. The curvature of these moulds may be shown by calculation thus: let R be the radius of curvature, $a =$ the semi-transverse axis, and $b =$ the semi-conjugate; then $b : a :: a : R = \frac{a^2}{b}$.

As, for example to this formula, let the radius of the cylindric intrados, or $b =$ 13 feet, and the semi-transverse axis, or $a = 28$ feet.

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To find the angle of the joints of the face of the arch, and intrados of the oblique arch with spiral joints.

Let the semicircular arc A B C, *Fig.* 4, be a section of the intrados at right angles to the axis of the cylinder. Draw C D and A E perpendicular to the diameter A C. Draw A D, making an angle with C D, equal to the inclination which the plane of the face of the arch makes with the vertical plane which is parallel to the axis of the cylinder, and which passes through the springing-line of the arch.

Find the edge D *f* G of the development and face of the arch, or draw the curve D *f* G with a mould made from the development before shown. Draw the face of the ring-stones A K D. Let it now be required to find the fourth from the point D. Make D *f* equal to the portion D 4 of the intrados A K D. Draw *f l*, the development of a part of the longitudinal spiral joint corresponding to the point 4 of the elliptic arc A K D. Draw the line $\varepsilon\, t$ a tangent to the curve at *f*. To do this, we shall again repeat the process of which the principle has already been taught, namely: — On C D, as a diameter, describe the semicircle C *q* D and draw *f q*, intersecting C D perpendicularly. Draw *q u* a tangent to the semicircular arc at the point *q*, and make *q u* equal to the development of the portion *q* D of the semicircular arc. Draw *u t* perpendicular to C D, meeting C D, or C D produced in the point *t*. Through *f* draw the straight line $t\varepsilon$, and $t\, \varepsilon$ will be a tangent to the curve at the point. By this means we have the angles which the spiral joints in the intrados make at the point 4 with the elliptic curve A K D.

To find the angle made by the normal and the curve, in *fig*. 4.

In *fig.* 7, draw the straight line *a b*, and make *a b* equal to the radius of curvature of the elliptic arc A K D at the point 4. This radius would be near enough to make it the half of the half sum of the semi-parameters of the two axes.

But if greater nicety is required, let the radius of curvature be denoted by *u*, the semi-transverse axis O D or O A be denoted by *a*, and the semi-conjugate, which is the radius of the semi-circular arc A B C, be denoted by *b*, and let the distance O *p* be denoted by *x*; then will $r = \left(\frac{a^4 - (a^2 - b^2)\, x^2}{a^4 b}\right)^{\frac{1}{2}}$; which will be exact to the number of figures found in the operation here indicated.

Having thus found the radius of curvature, either mechanically or by calculation, make *a b*, *fig.* 7, equal to that radius. From the point *a* as a centre, with the distance *a b*, describe the arc *b c*; and draw the straight line *b d* a tangent to the curve.

To find the angle made by a tangent plane to the cylindric surface at the point 4, *fig.* 4, and the plane of the face of the arch.

Draw the straight line 4 *u* a tangent to the elliptic curve A K D at the point 4, and draw 4 *v* parallel to A D. Transfer the angle *u* 4 *v* to *a b c*, *fig.* 5.

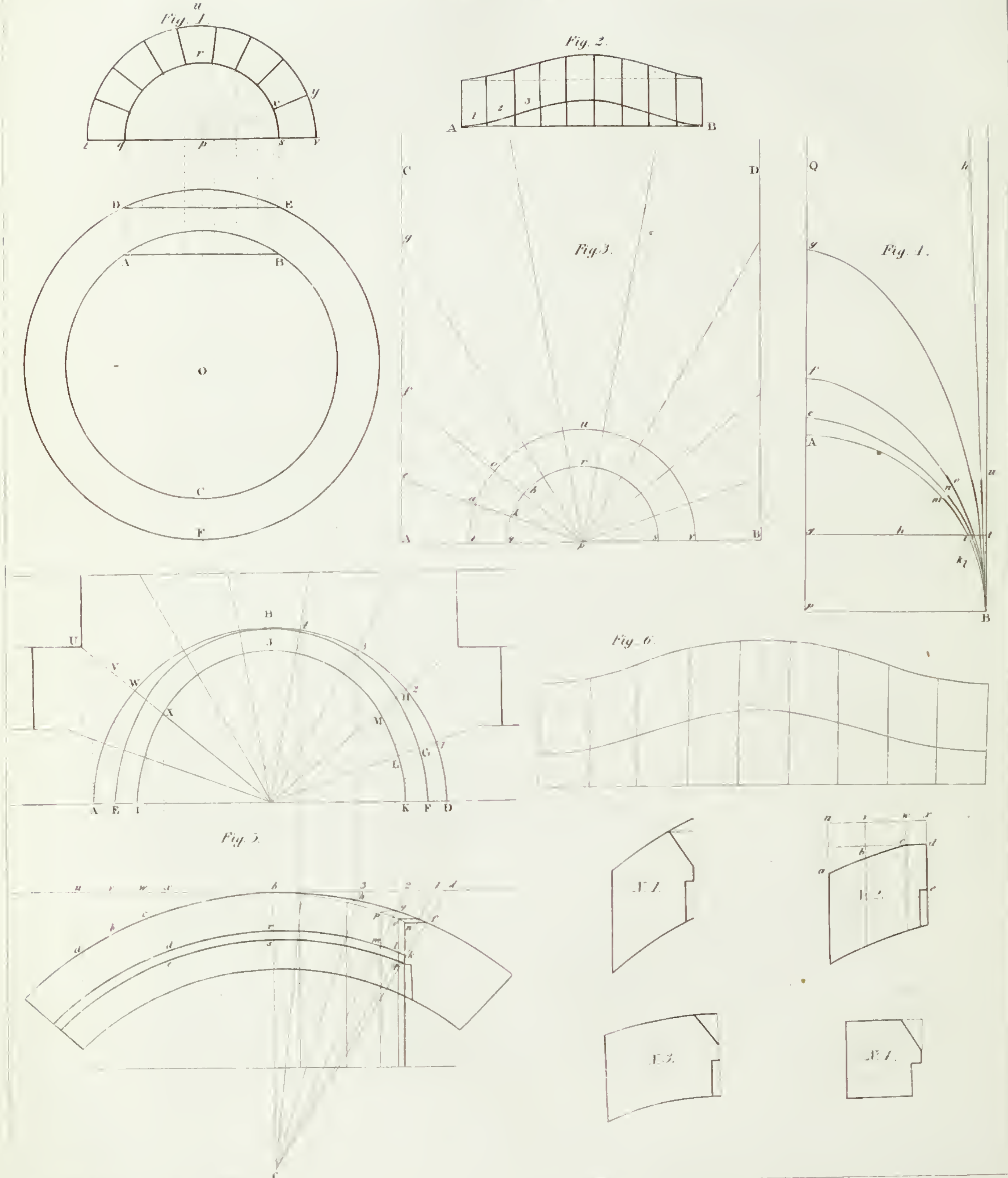
In *fig.* 5, at the point *b*, in the straight line *b c*, make the angle *c b d* equal to the angle D O P, *fig.* 3, which the axis makes with the plane of the face of the arch. Again, in *fig.* 5, draw *c f* perpendicular to *a b*, intersecting *a b* in the point *a*. Draw *c d* perpendicular to *c b*, and *c e* perpendicular to *c f*. Make *c e* equal to *c d*, and join *e a*; then will the angle *e a f* be the inclination of the curved surface of the cylindric intrados and the face of the ring-stones.

We have now ascertained two sides, and the contained angle of the trehedral; in order to find the remaining parts, the third side of this trehedral is the angle of the joints of the intrados and face of the arch, by applying the proper curved moulds to the angular point; it is, however, rather unfavorable to our purpose, that the angle *a b d*, *fig.* 7, is a right angle, and that the angles *l f t* and *l f ε*, *fig.* 4, differ but in a very small degree from right angles. As from this circumstance the principle cannot be made evident, we shall therefore suppose, that these angles have at least a certain degree of obliquity.

In *figs.* 3 and 5, let A B C equal to angle *l f t*, *fig.* 4, and A B D, *figs.* 3 and 6, equal to the angle *a b d*, *fig.* 7; thus, in *figs.* 3 and 6, draw D *e*, intersecting A B in *f*, or producing D *e* to meet A B in *f*. At the point *f* in the straight line *e f* in *fig.* 6, make the angle *e f g* equal to the angle *e a c*, *fig.* 5; or, in *fig.* 3, make the angle *e f g* equal to the supplement of the angle *e a f*. In *figs.* 3 and 6, draw *e k* perpendicular to B C, B C in *i*, or B C produced in *i*. Draw *e g* perpendicular to *e f*, and *e h* to *e* C. Make *e h* equal to *e g*, and join *h i*. Make *i* K equal to *i h*, and join B K; then will the angle C B K be the angle of the joints of the intrados and face of the arch.

Pl. 9.

# ARCHES



When each of the given sides is a right angle, then the remaining side of the trehedral will be the same as the contained angle; that is, the angle of the joints of the intrados and face of the arch will be the same as the angle *e a f*, *fig.* 5. In this case, no lines are necessary in order to discover the angle of the joints.

In order to apply the angle C B K, one of the lines which applies to the face must be straight, and the curved edge shown by the bevel at D of the preceding plate must be so applied, that the other leg of the bevel may be a tangent to the curve at the angular point B, and this will complete what is necessary in the construction of an oblique arch with spiral joints.

## SECTION VII. — A Circular Arch in a Circular Wall.

### PROBLEM I.

To execute a semi-cylindric arch in a cylindric wall, supposing the axes of the two cylinders to intersect each other. Given the two diameters of the wall, and the diameter of the cylindric arch, and the number of arch-stones.

*Fig.* 1, *Plate* IX. From any point *o*, with the radius of the inner circle of the wall, describe the circle A B C, or as much of it as may be necessary; and from the same point *o*, with the radius of the exterior face of the wall, describe the circle D E F, or as much of it as may be found convenient.

Apply the chord A B equal to the width of the arch, and draw D A and E B perpendicular to A B or D E; then A B D E will be the plan of the cylindric arch.

Draw O *p* perpendicular to A B, and draw *t v* perpendicular to O *p*. From the point *p* as a centre, with the radius of the intrados of the arch, describe the semicircular arc *q r s*; and from the same point *p*, with the radius of the extrados, describe the semicircular arc *t u v*. Divide the arc *q r s* into as many equal parts as the arch-stones are intended to be in number, that is, here into nine equal parts. From the centre *p*, draw lines through the points of division to meet the curve *t u v*; and these lines will be the elevation of the joints; and the joints, together with the intradosal and extradosal arcs, will complete the elevation of the arch.

Find the development, *fig.* 2, as in *fig.* 9, *Plate* IV., and the parallel equidistant lines to the same number as the joints in the elevation will be the joints of the soffits of the stones; and the surfaces comprehended by the parallel lines and the edges of the developments will be the moulds for shaping the soffits of the stones.

In *fig.* 3. Let A B be equal to the diameter of the external cylinder. Draw A C and B D each perpendicular to A B. Bisect A B in *p*, from which describe the intradosal and extradosal arcs, and draw the joints as in *fig.* 1. Produce the joints to meet A C or B D, in the points *e*, *f*, *g*, &c.; then it is evident that, since every section of a cylinder is an ellipse, the lines *p* A, *p e*, *p f*, *p g*, &c., are the semi-transverse axes of the curves which form the joints in the face of the arch, and that these curves have a common semi-conjugate axis equal to half the diameter of the cylinder.

Therefore, upon any indefinite straight line *p* Q, *fig.* 4, set off the semi-axis *p* A, *p e*, *p f*, *p g*, &c., and draw *p* B perpendicular to *p* Q. From *p*, with the radius *p* A, describe an arc A B. On the semi-axes *p e* and *p* B, describe the quadrantal curve of an ellipse; in the same manner describe the quadrantal curves *f* B, *g* B, &c. Make *p q* equal to *p q*, *fig.* 3, and in *fig.* 4 draw *q t* parallel to *p* B, intersect the curves A B, *e* B, *f* B, &c., in the points *i*, *k*, *l*, &c.; then *h i m*, *h k n*, *h l o*, &c., are the bevels to be applied in forming the angles of the joints; namely, the bevel *h i m* is that of the impost, the straight side *h i* being applied upon the soffit or intrados, and the curved part *i m* horizontally to the curve of the exterior side of the wall; the point *k*, of the bevel *h k n*, *fig.* 4, applies to the point *k*, *fig.* 3, so that *k h* may coincide with the joint upon the intrados, and the curved edge *k n*, *fig.* 4, upon the face *k n*, *fig.* 3; and so on.

As to the angles which the beds of the stones make with the intrados, they are all equal, and may be found from the elevation *s v y x*, *fig.* 1; which is the same as a section of one of the arch-stones perpendicular to any one of the joints on the soffits.

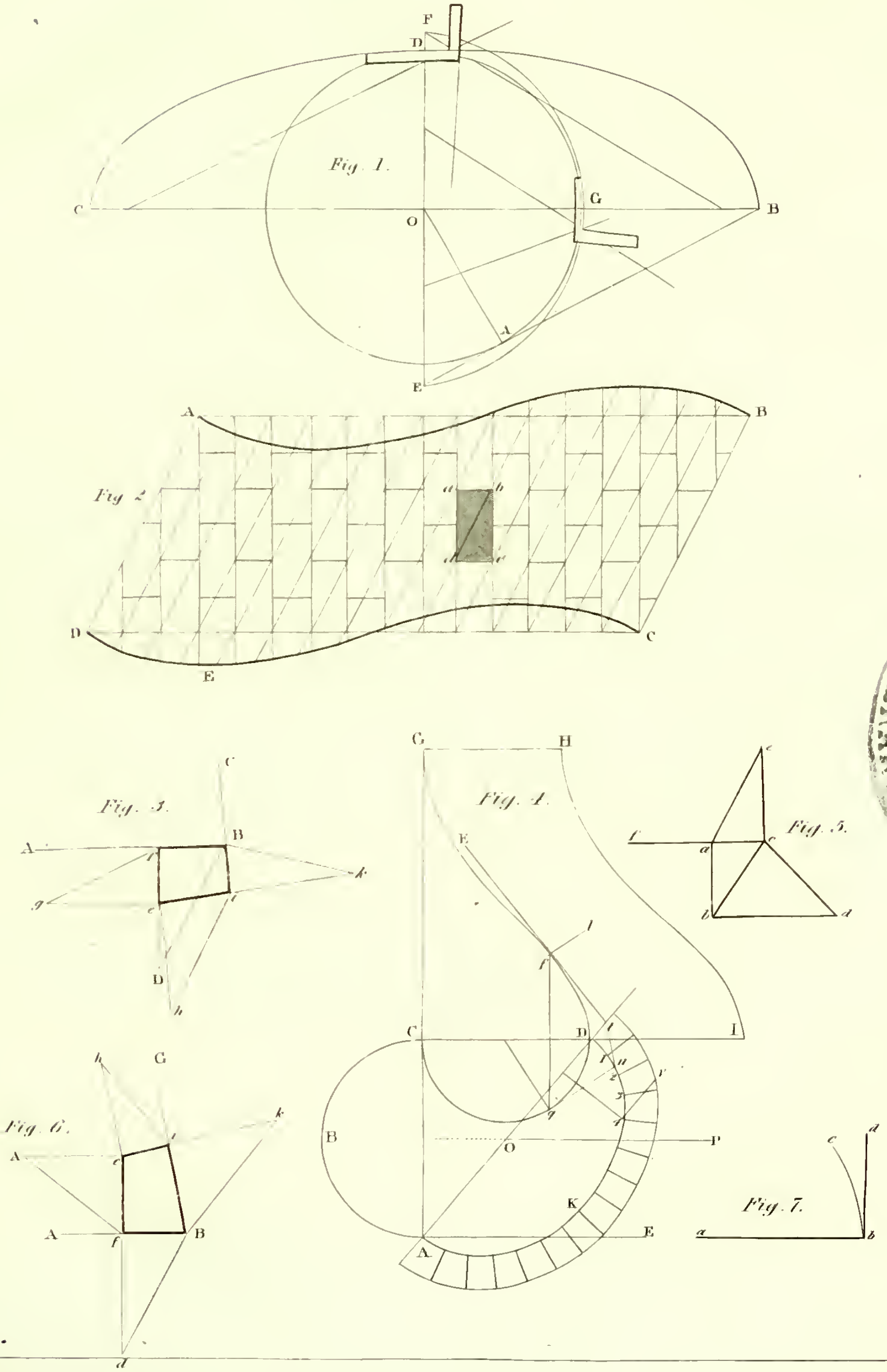
The faces of the stones must be wrought by a straight edge, by perpendicular lines. The first thing to be done is to work one of the beds; secondly, work the intrados, — at first as a plane surface at an angle *s x y*, or *x s v*, *fig.* 1; then gauge off the bed of the soffit, and work the other bed of the stone by the angle *v s x* or *y x s;* then apply the proper soffit, 1, 2, or 3, *fig.* 2; and lastly, the two moulds in *fig.* 4.

### SECTION VIII. — A Conic Arch in a Cylindric Wall.

#### PROBLEM I.

To execute a semi-conic arch in a cylindric wall, supposing the vertex of the cone to meet the axis of the cylinder. Given the interior and exterior diameters of the wall, the length of the axis of the cone, and the diameter of its base.

# TO FIND THE JOINTS OF STONE



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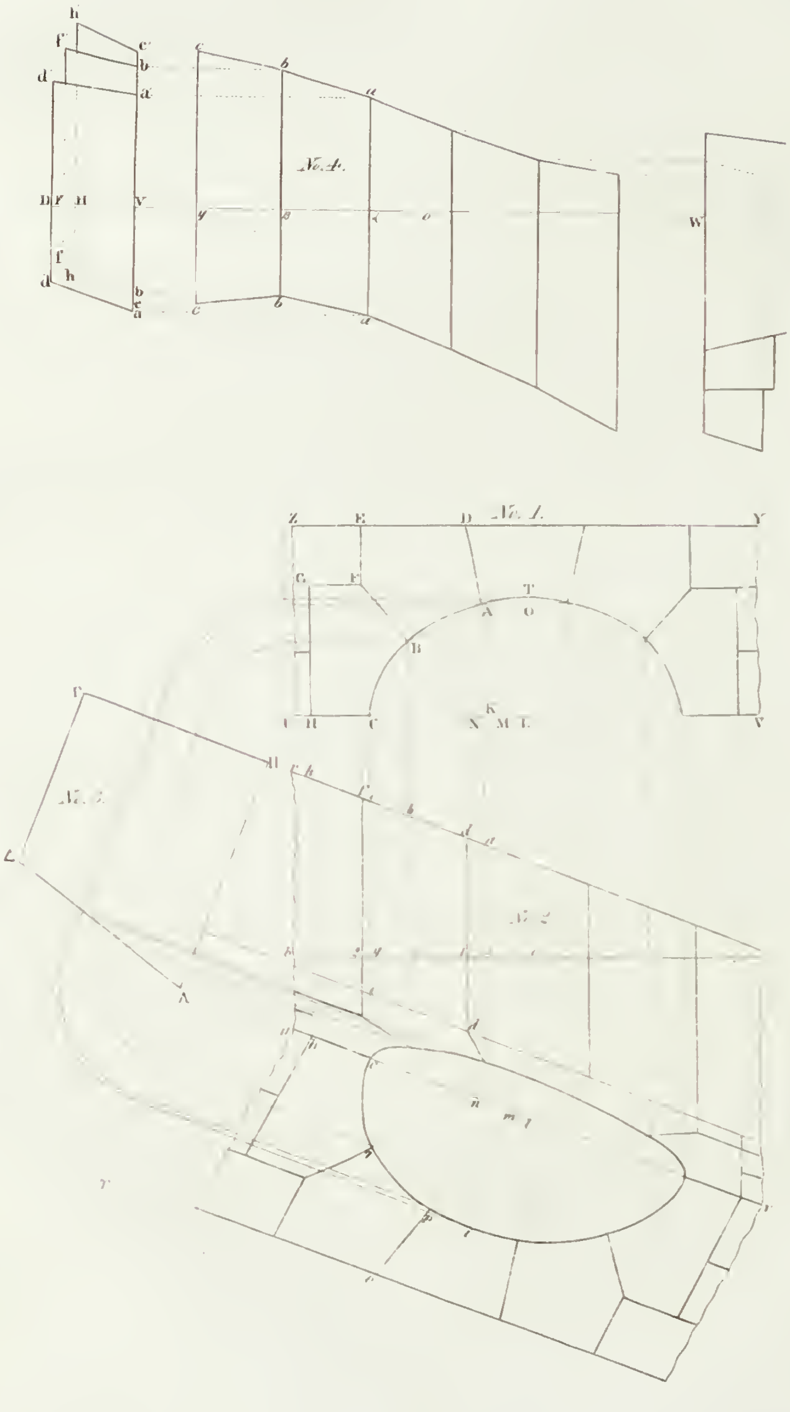
Pl II.

# RIGHT SECTION OF A VERTICAL PLANE

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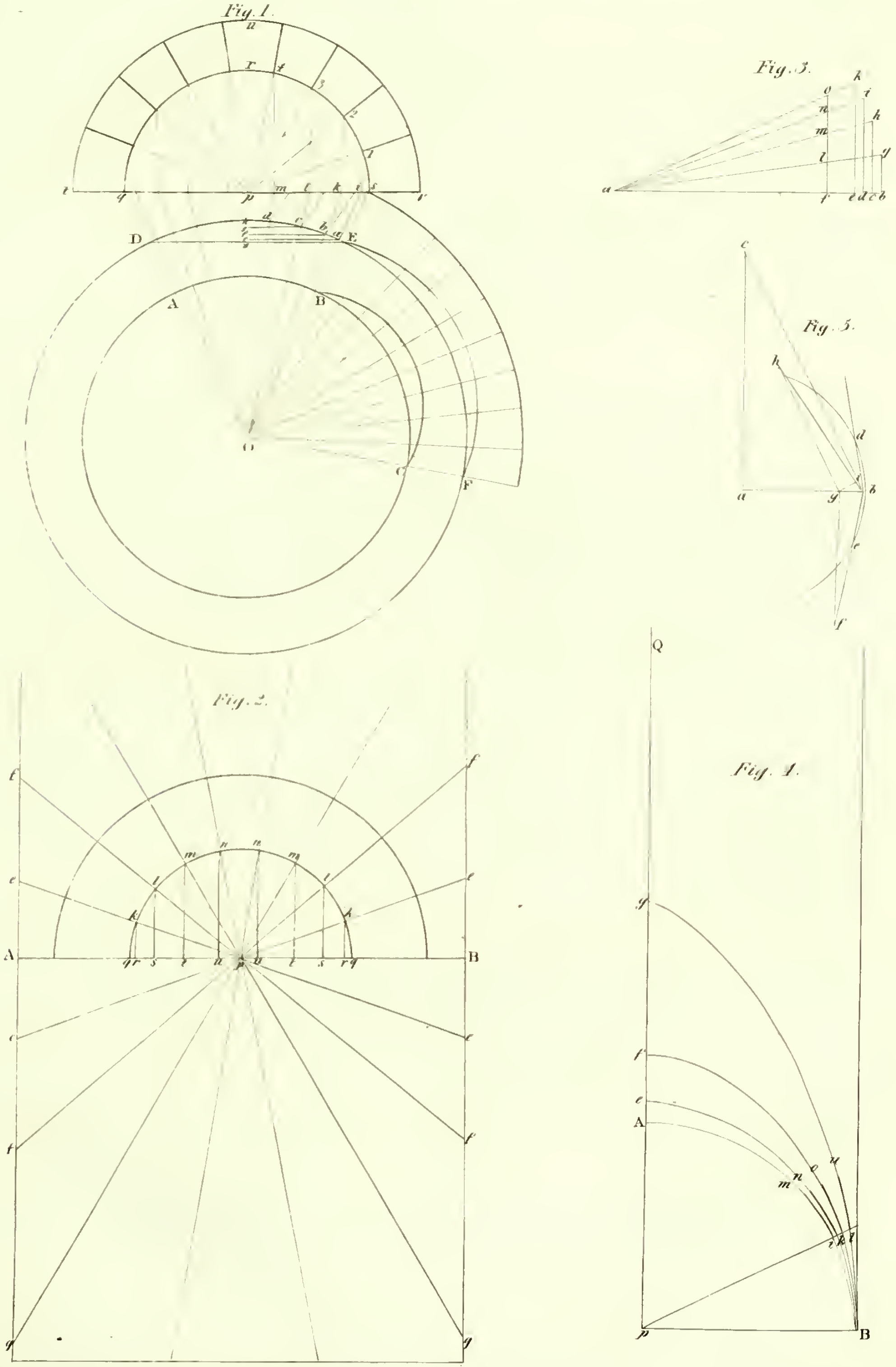
# ARCH IN A CIRCULAR WALL

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Example I. — From the point O, *fig.* 1, *Plate* XII., with the radius of the interior surface of the wall, describe the arc A B C, and from the same point O, with the radius of the exterior surface, describe the arc D E F, and the area between the arcs A B C and D E F will contain the plan of the wall.

Draw any line O *p*, and make O *p* equal to the length of the axis of the cone. Through *p* draw *t v* perpendicular to O *p*. From *p* as a centre, with the radius of the base of the cone, describe the semicircle *q r s* meeting *t v* in the points *q* and *s*. Divide the arc *q r s* into as many equal parts as the arch-stones are to be in number, that is, in this example, into nine equal parts. Through the points of division draw the joint lines, which will of course radiate from the centre *p*. The extradosal line *t u v* is here described, as we here suppose the cone to be of an equal thickness, and consequently the axis of the exterior cone longer than that of the interior.

From the points 1, 2, 3, &c., where the lower ends of the joints of the arch-stones meet the intradosal arc, draw lines perpendicular to *t v*, meeting *t v* in the points *i*, *k*, *l*, *m*, &c. From these points draw lines to the vertex of the cone at O, meeting the arc D E, or plan of the wall under the arch, in the points *a*, *b*, *c*, *d*, &c. Draw the lines *a e*, *b f*, *c g*, *d h*, &c., parallel to the chord D E, to meet *o p* in *w*. In *fig.* 2, draw the straight line A B, in which take the point *p* near the middle of it, and make *p* A, *p* B, each equal to the radius of the exterior surface of the cylindric wall. Through the points A and B draw *f g*, *f g*, perpendicular to A B.

From the point *p* as a centre, with any radius, describe a semicircular arc, and divide it into nine equal parts as before. Through the points of division draw the radiating lines to meet *f g* in the points *e*, *f*, *g*, &c. From *fig.* 1 transfer the distances E *w*, *a e*, *b f*, *c g*, &c., *fig.* 1, to *p g*, *fig.* 2, *p r*, *p s*, *p t*, &c., on each side of the point *p*. Draw the perpendiculars *r k*, *s l*, *t m*, &c., to A B, which will intersect with the radials *p e*, *p f*, *p g*, &c., in the points *k*, *l*, *m*, &c.; through the points *k*, *l*, *m*, &c., on each side, draw a curve, and this curve will be the elevation of the intrados of the arch.

*Fig.* 3 exhibits another method by which the heights of the points *k*, *l*, *m*, *fig.* 2, might have been found. This method is as follows: — Upon a straight line *a b*, and from the point *a*, make *a b'*, *a c*, *a d*, *a e*, &c., and *a f*, respectively equal to O *i*, O *k*, O *l*, &c., *fig.* 1. In *fig.* 3, draw the straight lines *b g*, *c h*, *d i*, *e k*, *f o*, perpendicular to *a b*. Make *b g*, *c h*, *d i*, *e k*, respectively equal to the heights *i* 1, *k* 2, *l* 3, *m* 4. Draw the straight lines *a g*, *a h*, *a i*, *a k*, intersecting *f o* in the points *l*, *m*, *n*, *o*.

In *fig.* 2, make *r k*, *s l*, *t m*, *u n*, respectively equal to *f l*, *f m*, *f n*, *f o*, *fig.* 2, and thus the points *k*, *l*, *m*, &c., are found by a different method, which is more

It will be necessary to work the arch-stones into prisms, of which the ends are the sections of the stones in the right section of the arch, namely, the same as the compartments adjacent to the curve in the elevation. The prisms being formed, draw the figure of the soffit of the stone upon the surface intended for the same. Then apply the joint-mould upon each face of the stone intended for the joint, and draw the figure of the joints; then reduce the end of the stone which is to form a part of the face of the arch in such a manner that when the arch-stone is placed in the position which it is to occupy, or in a similar situation, a straight edge, applied in a horizontal position, may have all its points in contact with the surface of the face of the stone now formed. The face being thus formed, the conic surface must also be formed by means of a straight edge, in such a manner that all points of the straight edge must coincide with the surface when the straight edge is directed to the centre of the cone.

### SECTION IX. — Construction of the Moulds for Spherical Niches, both with Radiating and Horizontal Joints, in Straight Walls.

When niches are small, the spherical heads are generally constructed with radiating joints meeting in a straight line which passes through the centre of the sphere perpendicularly to the surface of the wall, when the wall is straight; but when it is erected upon a circular plan, the line of common intersection of all the planes of the joints is a horizontal line tending to the axis of the cylindric wall.

Niches of large dimensions will be more conveniently constructed in horizontal courses, than with joints which meet in the centre of the spheric head; since, in the latter, the length and breadth of the stones are always proportional to the diameter or radius of the sphere, and therefore, when the diameter is great, the stones would be difficult to procure.

The construction of niches depends also upon the nature and position of the surface from which they are recessed; namely, a spherical niche may be made in a straight wall, either vertical or inclined; or it may be constructed in a circular wall or a spherical surface, such as a dome.

This subject, therefore, naturally divides itself under several heads or branches; the principal are, a spherical niche in a straight wall, with radiating joints; a spherical niche in a straight wall, in horizontal courses; a spherical niche in a circular wall, with radiating joints; a spherical niche in a circular wall, in horizontal courses; and a spherical niche in a spherical surface or dome.

*Pl 13.*

# ELEVATION OF A DOORWAY.

*Fig 1*

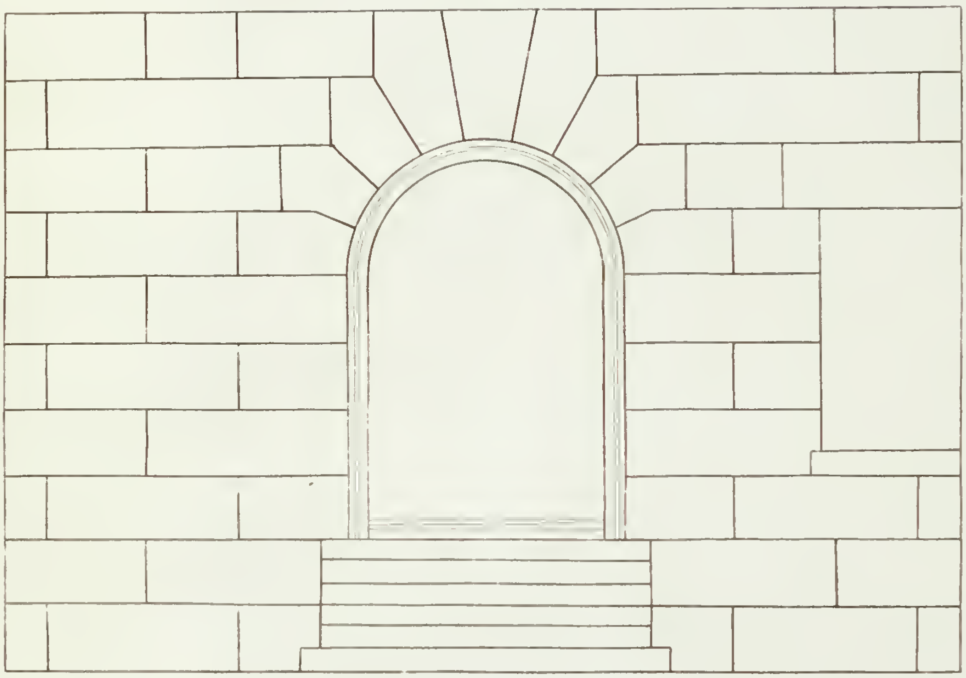


*Fig 2*

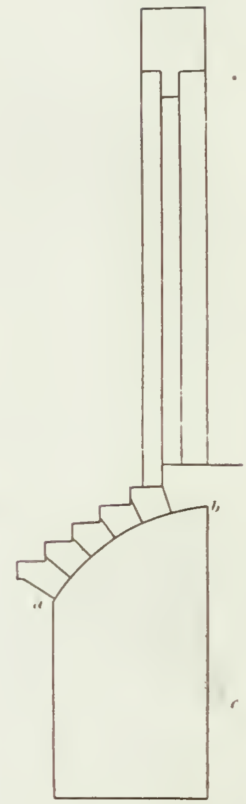
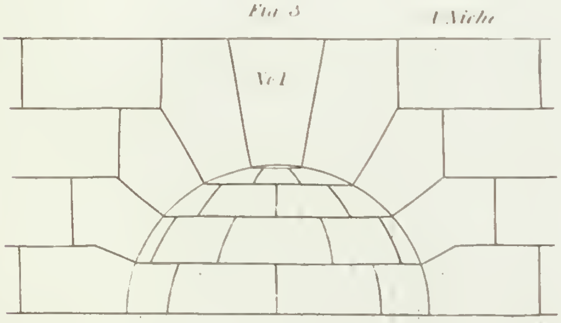
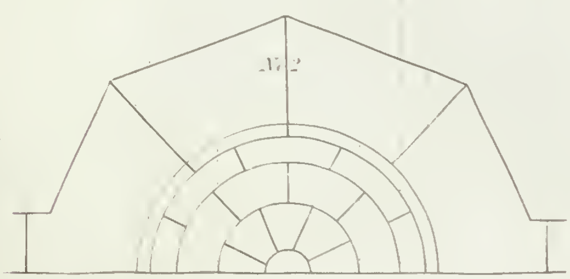



*Fig 3* — *A Niche*



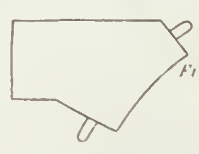



*Fig 4*

*Fig 5*

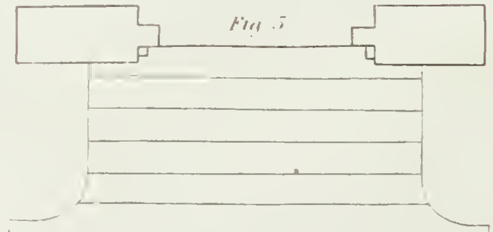
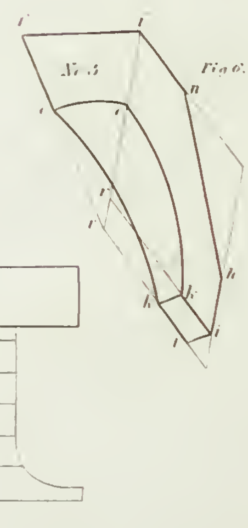


*Fig 6.*

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## SECTION X. — Examples of Niches, with Radiating Joints in Straight Walls, as in Plate XIII., Fig. 1.

Niches of very small dimensions will be easily constructed in two equal cubical stones, hollowed out to the spherical surface, with one vertical joint; the portion of the spherical surface formed by both stones being one fourth of the entire surface of the sphere.

*Fig.* 2 is the elevation, *fig.* 3 the plan, and *fig.* 4 the vertical section perpendicular to the face of the straight wall of such a niche.

The first operation is to square the stone; namely, to bring the head of each stone to a plane surface, then the vertical joints and the upper and lower beds to plane surfaces at right angles with the surface which forms the head.

The two stones as hollowed out are shown at Nos. 3 and 4. To show how they are wrought, we will commence with one of the stones after being brought to the cubical form. Let this stone be No. 3. In the solid angle of the stone formed by the head, the vertical joint and the lower bed meeting in the point *p*, apply the quadrantal mould, No. 2, upon each side, so that the angular point of the two radiants may coincide with the point *p*, and one of the radiants upon the arris of the stone which joins the point *p*; then if the face of the quadrantal mould coincide with the surface of the stone, the other radiant line will also coincide, because the angle of the mould and all the angles of the faces of the stone are right angles.

By this means we obtain, by drawing round the curved edge of the mould, the three quadrantal arcs *a b c*, *a g h*, and *c i h*. The superfluous stone being cut away, the spherical surface will be formed by trial of the mould, No. 2.

*Fig.* 1, *Plate* XIV., is the elevation, and *fig.* 2 the plan, of a niche in a straight wall.

The elevation, *fig.* 1, not only shows the number of stones which must be odd, and the number of radiating joints, which must in consequence be one less than the number of stones, but also the thickness of these stones, and the moulds for forming the heads and opposite sides.

The head of the niche being spherical, makes it a surface of revolution. It follows, therefore, that the sections through the joints are equal and similar figures; hence, if all the joints were of one length, one mould would be sufficient for the whole; but since, in this example, they are of different lengths, every two joint-moulds will have a common part; and thus if the mould for the longest joint be found, each of the other moulds will only be a part of the mould thus found.

In order to ascertain the mould for each joint, the longest being A D, *fig.* 1, extending from the centre to the extremity of the stone upon one side of the plan, the next longest is A F, extending from the centre to the extremity of the keystone, and the shortest A G.

Upon P Q, *fig.* 1, make A F equal to A F″, and A G equal to A G′. Perpendicular to P Q draw D *d*, F *f*, G *g*, meeting the front line R S of the plan, *fig.* 2, in the points *d*, *f*, *g*, intersecting the back line of the stone in the points *m*, *n*, *o*; then will No. 1, *h i k e d m*, be the mould for the first stone raised upon the plan, *h i k e f n* the mould for the joint on each side of the keystone, *h i k e g o* the mould for the first stone above the springing-line. These moulds are shown separately at I., II., III., and identified by similar letters.

Nos. 1, 2, 3, exhibit the first, second, and third stones of the niche as if wrought to the form of the spherical surface; No. 3 being the keystone; therefore the two remaining stones are wrought in a reverse order to the stones exhibited at No. 1 and No. 2.

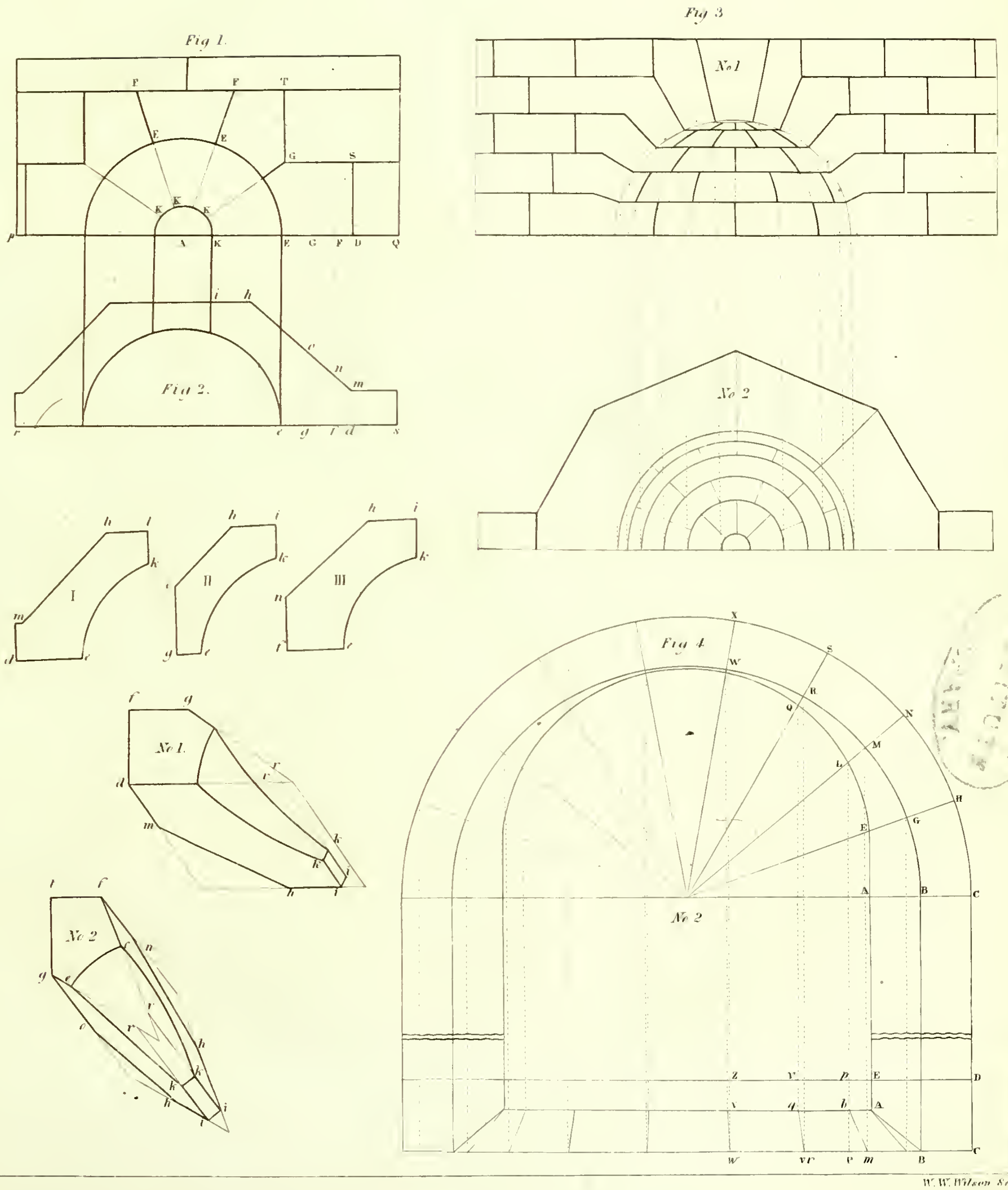
The first part of the operation is to work the stones into a wedge-like form, so that the right section of these stones may correspond to the figures formed by the radiations of the joints to the centre A, *fig.* 1, and by the horizontal and vertical joints of the stones adjacent to those which form the niche; for this purpose, two moulds for each head will be necessary, namely, one whole mould must be made for each stone, and one mould for the part within the circle, which will apply to every stone, in order to form the extent of the part within the recess; thus a mould formed to the sectoral frustrum E E′ K′ K in the elevation, *fig* 1, will apply alike to all stones, as will be shown presently.

The next thing is to form the moulds K′ K D S G′, K″ K′ G′ T F″, and K″ K″ F″ F″, of the heads; the application of these moulds is as follows: —

Having wrought the under bed, the head and back of each stone, and having formed a draught next to the edge of the bed, upon the side which is to lie upon the cylindric part in the centre, at a right angle with the head, apply the mould K′ K D S G′, *fig.* 1, upon the head of the stone No. 1, so that the straight edge K D may be close upon the bed of the stone, and draw by the other edges of the mould thus applied the figure *r′ r d s g*; and, in the same line *r d*, close to the bed, apply the mould K′ K E E′, *fig.* 1, and by the other edges of this mould draw the figure *r′ r e e′*. Apply the mould K′ K D S G′ to the opposite or parallel side of the stone, close to the bed, and draw a similar and equal figure as was done by the same mould when it was applied to the head; this done, work the upper bed of the stone.

Proceed in like manner with the stones exhibited at No. 2 and No. 3, and similarly with the stones on the left-hand side of the arch; the stones No. 1 and No. 2 answering to those on the right hand of the keystone.

# NICHES.

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*Pl. 15.*

# NICHES

*Fig 2.*

*Fig 1.*

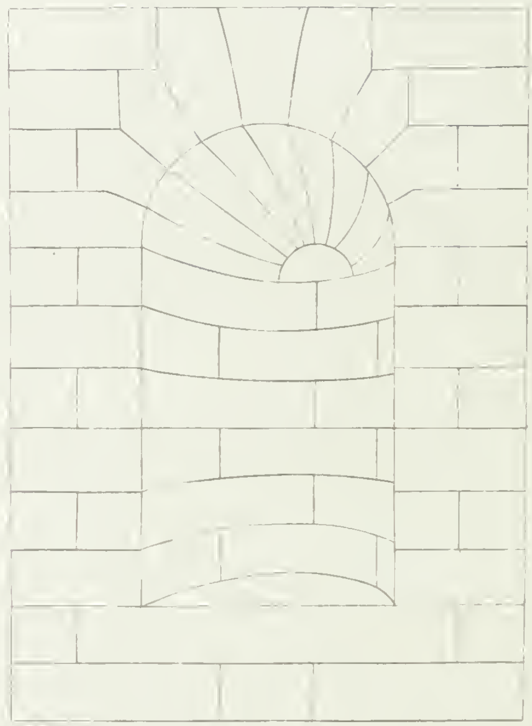
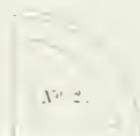


*Fig 3.*

*Fig 4.*

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In order to show the application of the moulds marked I., II., III., at the bottom of the plate, taken from the plan, *fig.* 2; the mould I. applies to the under bed of the stone No. 1; the next mould II. applies upon the upper bed of No. 1, and upon the under bed of No. 2; and the mould III. applies upon the upper bed of No. 2, and upon each side of the keystone, No. 3.

As every arch has both a right and left hand side, and as every joint is formed by the surfaces of two stones, every mould has four applications, one on each of the four stones.

In order to render these applications of the moulds I., II., III., as clear as possible, the corresponding situations of the points marked upon each stone by each respective mould are marked by similar letters to those on the moulds I., II., III., or their correspondents on the plan, *fig.* 2; namely, on the under bed of the stone No. 1 will be found the letters *h, i, k, e d, m*, as in the mould I.; upon the under bed of No. 2 will be found $h', i', k', e', g', o'$; as also upon the upper bed of No. 1, $i', k', e,' g'$, and upon the right-hand side of the keystone, No. 3, will be found the letters $h'', i'', k'', e'', f'', n''$, as also similar letters upon the upper bed, No. 2, to those of the mould III.

### ARCH, WITH SPLAYED JAMBS.

To find the angles of the joints formed by the front and intrados of an elliptical arch, erected on splayed jambs.

No. 1, on *fig.* 3, is the place of the impost; No. 2, the elevation.

The impost A′B′C′D′E is the first bed; *fghik*, the second; *lmnop*, the third; *qrstu*, the fourth; *vwxyz*, the fifth. The other beds are the same in reverse order. The breadth of all these beds is the same as that of the arch itself. The lengths *k* K, *n* P, *s* U, *x* Z, of the front lines of the moulds of the beds are respectively equal to the lines H F, N L, S Q, X V, on the face of the arch. And also, *h g*, *n m*, *s r*, *x w*, on the parts of the moulds equal to the corresponding distances H C, N M, S K, X W, on the face of the arch. The distances *kf*, *p l*, *u g*, *r v*, are equal to the perpendicular part A E of the impost.

## SECTION XI.—Examples of Niches in Straight Walls with Horizontal Courses, as in Plate XIV., Fig. 1.

Let *fig.* 2 represent a niche with horizontal courses, No. 1 being the elevation exhibiting three arch-stones on each side of the keystone, and No. 2 the plan, consisting of two stones, making together a semicircle, each being one quadrant.

The heads of the stones in the wall, on the right-hand side of the arch, which also form a portion of the concave surface, are A B C D E, F D C G H M, M G K L M, and the keystone L K K L. Round each of these figures circumscribe a rectangle, so that two sides may be parallel and two perpendicular to the horizon; thus, round the head of the stone A B C D E circumscribe the rectangle A N O E′; round the figure F D C G M I, the head of the second stone, circumscribe the rectangle P Q R I, &c.

Draw the straight lines *a m* and *a i*, *fig*. 3, No. 1, forming a right angle with each other; from the point *a* as a centre, with the radius *d b c*, describe the arc *c c′*, meeting the lines *a m* and *a i* in the points *c*, *c′*.

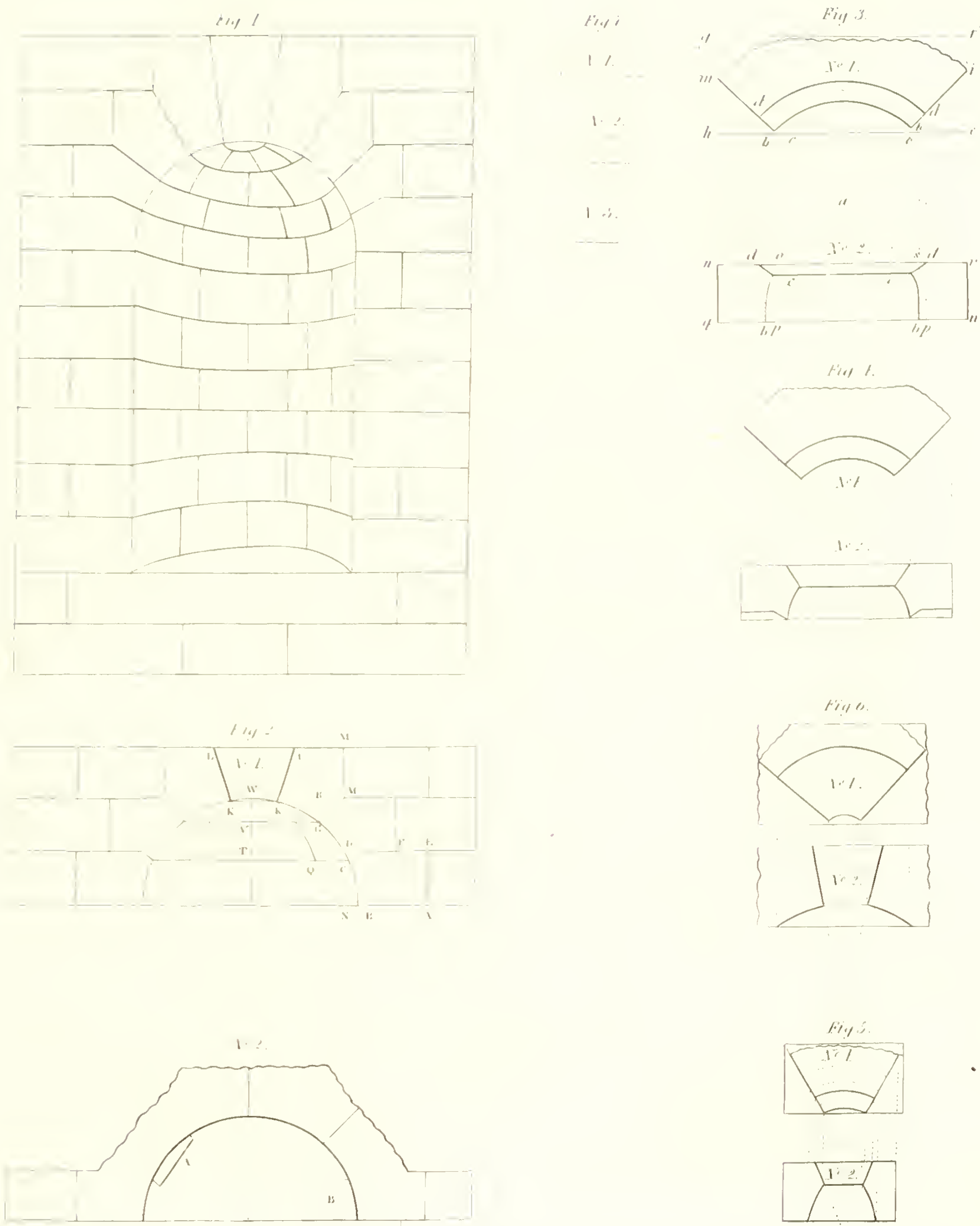
Let the quadrangular figure *h g f e*, No. 1, be considered as the upper bed of a stone, which, as well as the lower bed, is wrought smooth, these two surfaces being parallel planes at a distance from each other equal to the line A E or C D, *fig*. 2. Moreover, let *m c c′ b b d d* be considered as a mould made to the figure before described and laid flat on the upper bed of the stone in its true position, the points *c*, *c′*, of the mould being brought as near to the side *h e* as will just leave a sufficient quantity of stone, in order to work it complete. By the edges of the mould thus placed, draw the curve *c c′*, the straight lines *c m* and *c′ i*, and the rough edges *i k* and *m l*.

Perpendicular to the upper bed, and along the arc *c c′*, cut the stone so as to form a surface perpendicular to the upper bed, and the surface thus formed will necessarily be cylindric; through each of the straight lines *c m* and *c′ i* cut a surface perpendicular to the said upper bed, and these surfaces will be the planes of the vertical joints, and will be at a right angle with each other; then with a gauge, of which the head is made to the cylindric surface, and which is set to the distance O D, *fig*. 2, No. 1, draw the curve line *d d* on the upper bed of the stone. Upon the lower bed of the stone, with the gauge set to the distance N B, draw the arc *b b′*.

The thickness of the stone is exhibited at No. 2, *fig*. 3, the upper bed being represented by the line *n r*, and the lower bed by the line *q u*, so that *n r* and *q u* are parallel lines, the distance between them being equal to the thickness of the stone, namely, equal to A E, *fig*. 2, No. 1. Lastly, with a plane or common gauge set to the distance N C, *fig*. 2, No. 1, draw the line *c c* on the cylindric surface, *fig*. 3, No. 1.

Now, in *fig*. 3, the line *d d′*, No. 2, represents the arc *d d′*, No. 1; *c c′*, No. 2, represents the arc *c c′*, No. 1; and *b b′*, No. 2, represents the arc *b b*, No. 1; so that the stone must be cut away between the line *d d′* on the upper bed, and *c c′* on the cylindric surface, by means of a straight edge, so as to form a conic surface; this may be done by setting a bevel to the angle E D C, *fig*. 2, No. 1. The conic surface thus formed will be one side of the joint within the spheric surface.

# NICHES



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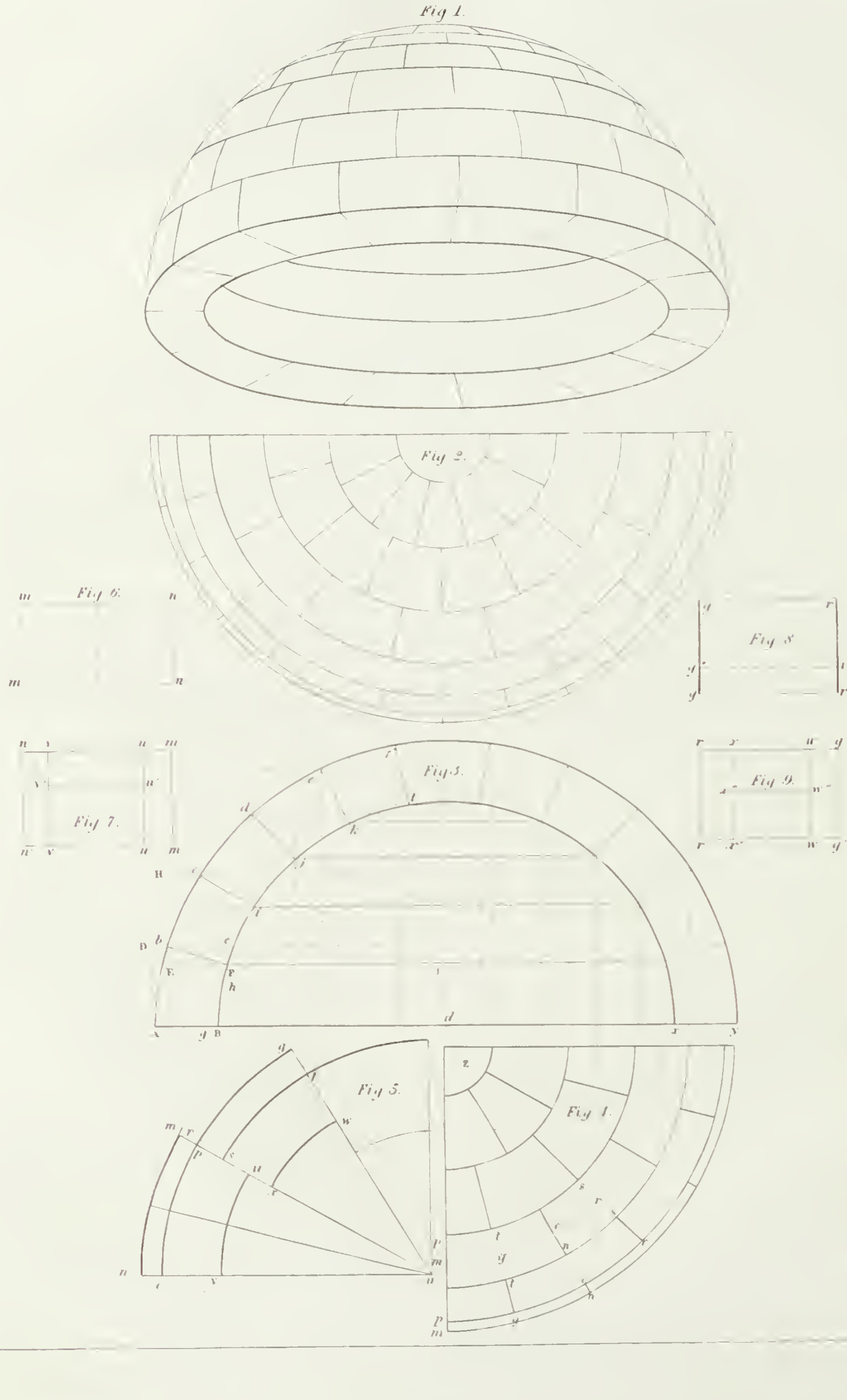
Pl 17.

# A DOME.

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Again, cut away the stone between the line $c\,c'$ on the cylindric surface and the arc $b\,b'$ before drawn on the lower bed by means of the curved bevel shown at A, *fig.* 2, No. 2, so as to form a spherical surface. This may be done in the most complete manner by applying the straight side of the curved bevel B, *fig.* 2, No. 2, to the under bed of the stone, so as to be perpendicular to the curve; then, if the curved edge coincide at all points, the surface between these lines will be spherical, and will form that portion of the head of the niche which is contained on the stone.

In the same manner all the other stones may be cut to the form required.

*Fig.* 4 exhibits the stone in the middle of the second course, and *fig.* 5 the stone on the left of the same course in the angle, which last stone is one half of the stone represented by *fig.* 4.

*Fig.* 6 exhibits the left-hand stone of the third course, and *fig.* 7 the keystone, which is wrought into the frustrum of a cone to a given height, in order to agree with the circular courses; and to prevent any tendency of the keystone from coming out of its place, the upper part is cut into the frustrum of a pyramid.

*Plate* XV., *fig.* 3, represents a spheric-headed niche in a straight wall, with four arch-stones on each side of the keystone, and therefore also with four horizontal courses; and as the joints are broken, if we begin the first course with four whole stones, as exhibited on the plan, No. 2, the next course will consist of three whole stones and two half stones in one in each angle. As the stones are here in this example projected on the plan as well as on the elevation, the elevation, No. 1, not only exhibits the number of courses, but the number of stones also in each course.

*Fig.* 2 represents a spheric-headed niche in four courses besides the keystone. No. 2, the ground-plan of No. 1.

It may be observed, once for all, that the greater the dimensions of a niche, the greater must also be the number of courses in the height.

The principles for cutting the stones of these niches is the same as has already been explained for Plate XIV.

## SECTION XII. — Construction of the Moulds, and Formation of the Stones, for Domes upon Circular Planes, as in Plate XVII., Figs. 1 and 2.

### ON THE CONSTRUCTION OF SPHERICAL DOMES.

Since walls and vaults are generally built in horizontal courses, the sides of the coursing-joints in spherical domes are the surfaces of right cones, having one common vertex in the centre of the spheric surface, and one common axis; hence the conic surfaces will terminate upon the spheric surface in horizontal circles: again, because the joints between any two stones of any course are in vertical planes passing through the centre of the spheric surface, the planes passing through all the joints between every two stones of every course will intersect each other in one common vertical straight line passing through the centre of the spheric surface.

The line, in which all the planes which pass through the vertical joints intersect, is called the axis of the dome.

Because a straight line drawn through the centre of a spheric surface, perpendicular to any plane cutting the spheric surface, will intersect the cutting plane in the centre of the circle of which the circumference is the common section of the plane and spheric surface, the axis of the dome will intersect all the circles parallel to the horizon in their centre.

The circumference of the horizontal circle, which passes through the centre of the spheric surface, is called *the equatorial circumference*, and any portion of this circumference is called *an equatorial arc.*

The circumferences of circles, which are parallel to the equatorial circle, are called *parallels of altitude*, and any portions of these circumferences are called *arcs of the parallels of altitude.*

The intersection of the axis and the spheric surface is called *the pole of the dome.*

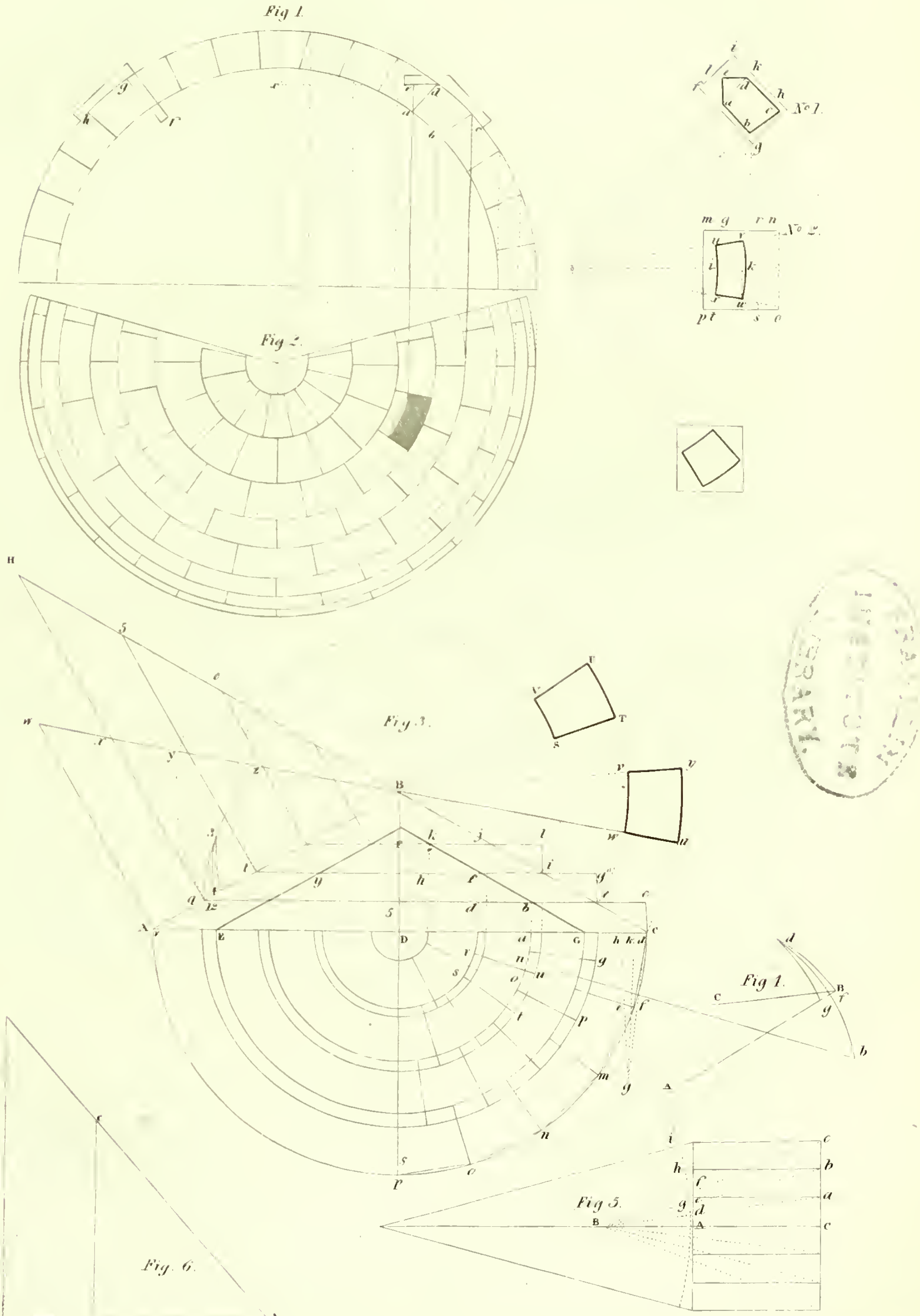
The arcs between the pole and the base of the dome, of the circles formed on the spheric surface by the planes which pass along the axis, are called *meridians*, and any portions of these meridians are called *meridional arcs.*

The conical surfaces of the coursing-joints terminate upon the spheric surface of the dome in the parallels of altitude, and the surfaces of the vertical joints terminate in the meridional arcs.

Hence in domes, where the extrados and intrados are concentric spheric surfaces to apparent sides of each stone contained by two meridional arcs, and the arcs of two parallel circles are spheric rectangles, the two sides which form the vertical joints are equal and similar frustrums of circular sectors, and the other two sides, forming the beds, are frustrums of sectors of conic surfaces.

In the execution of domes, since the courses are placed upon conical beds which terminate upon the curved surfaces in the circumferences of horizontal circles, they are comprised between horizontal planes, and therefore may be said to be horizontal. Hence the general principle of forming the stones of a niche constructed in horizontal courses may likewise be applied in the construction of domes.

# SECTION OF A DOME.

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Each of the stones of a course is first formed into six such faces as will be most convenient for drawing the lines, which form the arrises between the real faces. Two of these preparatory faces are formed into uniform concentric cylindric surfaces, passing through the most extreme points of the axal section of the course in which the stone is intended to be placed, the axis of the dome being the common axis of the two cylindric surfaces of every course.

Two of the other surfaces are so formed as to be in planes perpendicular to the axis of the dome, and to pass through the most extreme points of the axal or right sections of the course, as was the case with the two cylindric surfaces.

The extreme distance of the two remaining surfaces depends upon the number of stones in the course. These surfaces are in planes passing through the axis, and are therefore perpendicular to the other two planes. As these planes, which pass through the axis, from the vertical joints, they remain permanent, and undergo no alteration except in the boundary, which is reduced to the figure of the axal section of the course.

In order to find the terminating lines of the last and permanent faces, draw the figure of the section of the course upon one of the two vertical joints in its proper position, then two of the corners of the mould will be in the two cylindric surfaces, one point in the one, and the other in the other, and the two remaining corners of the mould will be in the two surfaces which are perpendicular to the axis, one point of the mould being in the one plane surface, and the other point in the other plane surface.

Draw a line on each of the cylindric surfaces through the point where the axal section meets the surface parallel to one of the circular edges, and the line thus drawn on each of the cylindric surfaces will be the arc of a circle in a plane perpendicular to the axis of the two cylindric surfaces, and will be equal and similar to each of the edges of the cylindric surface to which it is parallel; but in the first course of a hemispheric dome, there will be no intermediate line on the convex side, since the circular arc terminating the lower edge will also be the arris-line of the convex spheric surface and the lower bed of the stone, which in this course is a plane surface.

In all the intermediate courses of the dome between the summit and the first course, the line drawn on the convex cylindric surface will be the arris-line between the convex spheric surface and the convex conic surface which forms the lower bed of the stone; and in all the courses from the base to the summit, the line drawn on the concave cylindric surface will be the arris-line between the concave conic surface forming the upper bed and the concave spheric surface of the stone, which concave surface will form a portion of the interior surface of the dome.

On the upper plane surface of each stone to be wrought for the first course, draw a line parallel to one of the circular edges; but in each of the stones for the intermediate courses between the first course and the keystone at the summit, draw a line on each of the planes which are perpendicular to the axis parallel to either of the edges of the face upon which the line is made through the common point in the vertical plane of the joint and the horizontal plane, then the line drawn on the top of every stone will be the arris-line between the convex spheric and the concave conic surfaces to be formed, and the line drawn on the under side of any stone in each of the intermediate courses will be the arris between the convex conic and the concave spheric surfaces to be formed; that is, between the surfaces which will form the lower bed and a portion of the interior surface of the dome.

Draw the form of the section of the course upon the plane of the other joint, so that the corners of the quadrilateral figure thus drawn may agree with the four lines drawn on the two cylindric and on the two parallel plane surfaces.

Lastly, reduce the stone to its ultimate figure by cutting away the parts between every two adjacent lines which are to form the arrises between every two adjacent surfaces, until each surface acquire its desired form.

Each of the spherical surfaces must be tried with a circular edged rule, in such a manner that the plane of curve must in every application be perpendicular to each of the arris-lines, the mould for the convex spheric surface being concave on the trying edge, which must be a portion of the convex side of the section, *fig.* 1, and the mould for the concave side convex on the trying edge, and a portion of the concave arc forming the inside of the section.

The two conical surfaces of the beds, and the two plane surfaces of the vertical joints, must be each tried with a straight edge, in such a manner that the trying edge must always be so placed as to be in a plane perpendicular to each of the circular terminating arcs; so that the surfaces between these arcs must always be prominent until the trying edge coincide with the two circular edges, and every intermediate point of the trying edge with the surface.

*Fig.* 3, Let A *b c d e f* . . . . *y* be the exterior curve of the section divided into the equal parts A *b*, *b c*, *c d*, &c., at the points *b*, *c*, &c., so that each of the chords A *b*, *b c*, *c d*, &c., may be equal to the breadth of the stones in each of the circular courses; also let *g h i j k l* . . . . *x* be the inner curve of the section, divided likewise into the equal arcs *g h*, *h i*, *i j*, &c., by the radiating lines *b h*, *c i*, &c.; hence A *b h g* is a right section of the first course; and, therefore, the figure of the joint at each end of every stone in the first course; likewise *b c i h* is the right section of the second course; and, therefore, the figure of the joint at each end of every stone in the second course.

Since the entire exterior curve of the axal section of the dome is divided into equal parts alike from the basis on each side of the section; and since the exterior and interior sides of the section are each a semicircular arc, and described from the same centre; and since the dividing lines *b h*, *c i*, &c., radiate to this centre, all the sections of the courses and the boundaries of the vertical joints will be equal and similar figures; and, therefore, a mould made to the figure of the section of any course will serve for the vertical joints of all the stones.

*Fig.* 4 exhibits one fourth part of the plan of the convex side of the dome, showing the number of courses and the number of stones in each quarter-course, there being three stones of equal length in each quarter-course.

In the first or bottom course, *m n o p* is the plan of the convex side of one of the stones, and *m′n′o′p′* the plan of the concave side of the same stone; and, in the second course, *q r s t* is the plan of the convex side of one of the stones, and *q′r′s′t′* is the plan of the concave side of the same stone; so that in the first course *m n o′p′* is the figure of the top and bottom of one of the ring-stones, *p o* is the intermediate line on the top, and *m′n′* that on the bottom, and so on for the remaining stones.

All the stones of any course being equal and similar solids, and alike situated, the same mould which serves to execute any stone of any one course will serve to execute every stone of that course; but every course must have a different set of moulds from those of another, except the figures of the vertical joints, which will be all found by one mould, as has been already observed.

The reader, who has a competent knowledge of the construction of niches in horizontal courses, will not be at any great loss to understand the construction of domes; or if the construction of domes is well understood, he cannot be at any loss to comprehend the construction of niches; however, as there are many observations respecting the construction of domes that do not apply to niches, particularly as the dome in the present article has two apparent sides, in order to prevent the reader from wasting his time in referring to both articles, we shall here conduct him through the formation of one of the stones in the first two courses, the figure of the stones in the remaining courses being found in a similar manner.

In *fig.* 3, draw A D perpendicular to the ground-line A *y*, and through *h* draw B C also perpendicular to the ground-line A *y*. Now A B as well as A *g* being upon the ground-line, therefore to complete the rectangle A B C D, so as to circumscribe the section A *b h g*, and to have two vertical and two horizontal sides, draw through the point *b* the remaining side D C parallel to A *y*.

The rectangle A B C D is the section of a circular course of stone, or that of a ring contained by two vertical concentric uniform cylindric surfaces and by two horizontal plane rings, the radius of the concave cylindric surface being *a* B, and the radius of the convex cylindric surface being *a* A, and the height of the ring being A D or B C.

Make a mould to the plan of one of the stones in the first course, that is, to *m n o p*, *fig.* 4.

From any point *y*, *fig.* 5, with a radius *z m*, *fig.* 4, or the radius *a* A, *fig.* 3, describe the arc *m n*. Make the arc *m n*, *fig.* 5, equal to the arc *m n*, *fig.* 4, and draw the lines *m u* and *n v* radiating to the point *y*. Again, from the centre *y*, and with the radius *a* B, *fig.* 3, describe the arc *v u*.

Make a face-mould to *m n v u*, and this mould will serve for drawing the figure of the two horizontal surfaces of each stone in the first or bottom.

To cut one of the stones in the first course to the required form: — Reduce the stone from one of the sides till the surface becomes a plane. Apply the mould made to the figure *m n v u* on this surface, which is one of the two horizontal faces, and having drawn the figure of the mould, reduce the stone so as to form three of the arris-lines of the faces, which are to be vertical, and these arrises will be square to the face already wrought. On each of the three arrises thus formed, set the height of the stone from the plane surface already made; reduce the substance till the surface becomes a plane parallel to that first formed.

Apply then the face-mould *m n v u* upon the plane surface last wrought, so that three points of the mould may join the corresponding points in the meeting of the three arrises, and, having drawn the figure of the mould upon the second formed face, run a draught on the outside of each line upon each of the intermediate surfaces from each of the parallel faces. So that there will be four draughts receding from the face first formed, and four receding from the face last formed, and that upon the whole, including the two draughts upon each side of each of the four perpendicular arrises, there will be sixteen in all.

The two draughts along the edges of the convex cylindric surface to be formed must be tried with a concave circular rule, made to the form of the arc *m n*, *fig.* 4, and the two draughts along the edges of the concave cylindric surface must be tried with a convex circular rule made to the form of the arc *p o*, *fig.* 4. Moreover, the two draughts which are made along each of the edges of each opposite intermediate plane surface must be tried with a straight edge.

Having regularly formed the draughts, so that the circular and straight edges of each of the three rules may coincide in all points with the bottom surface of each respective draught, and with the arris-line at each extremity, the workman may then cut away the superfluous parts of the stone, as far as he can discern to be just prominent, or something raised above the four draughts, bordering the four edges of each of these surfaces.

The rough part of the operation being done, each of the four intermediate faces may be brought to a smooth surface and to the required form, by means of a common square; the face of coincidence of the stock, or thick leg, being applied upon one of the two parallel faces, and the thin leg, called the blade, to the surface of the stone, in the act of reducing, until it has acquired the figure desired, or the two cylindric surfaces may also be tried by means of circular edged rules, the edge of each rule being placed so as to be parallel to one of the parallel faces; a concave circular edge being applied upon the convex side, and a convex circular edge upon the concave side.

The six faces which contain the solid being thus formed, we shall now proceed to find the upper arris: — for this purpose apply the mould made to the form *m n o p*, *fig.* 4, upon the top of the stone drawn by the means of the mould *m n v u*, *fig.* 5.

Suppose *m n v u*, *fig.* 5, to be the figure drawn on the top of the stone itself, by means of the mould made to *m n v u;* and *m n o p*, *fig.* 5, to be the mould made from *m n o p*, *fig.* 4. Lay the edge *m n*, *fig.* 4, upon the edge *m n*, *fig.* 5, on the top of the stone, so that the equal circular arcs may coincide in all their points; and draw the line *o p* along the concave edge of the mould, and *o p* will be the arris-line of the spherical and conical surfaces which are yet to be formed.

Let the rectangle *m n n′m′*, *fig.* 6, be the elevation of the convex cylindric surface of the same stone, projected on a plane parallel to each of the chords of the circular arcs and to one of the straight arrises of this surface; the straight line *m n* representing the upper circular edge, *m m*, *n n′*, the two vertical arrises; so that the convex spherical surface is terminated at the top by the arc *o p* and at the bottom by the arc *n′m′*.

Let the rectangle *n m m′n′*, *fig.* 7, be the elevation of the concave cylindric face, projected on a plane parallel to one of the chords of one of the circular boundaries and to one of the straight-lined boundaries of this face; then the upper and lower planes will be projected into the parallel lines *n m*, *n′m′*. Therefore all the lines of each of these three planes will be projected upon the lines *n m*, *n′m′*, and as the rectilineal figure formed by the two chords and the two straight lines is parallel to the plane of projection, it will be projected into an equal and similar figure; therefore the projected figure is a rectangle, and the sides *n m*, *n′m′*, are equal to each other, and to the chords of the two circular arcs; and the lines *m′m*, *n n′*, are each equal to the height of the hollow cylinder, or equal to the distance between the parallel planes.

Hence the concave surface will be projected also into a rectangle, and the middle of the chords of the arcs terminating the parallel edges of the concave surface upon the middle of the chords of the arcs terminating two of the opposite edges of the convex surface, as also the two opposite parallel straight-lined sides in the height of the solid will be projected into straight lines equidistant from the projections of the corresponding lines in the height of the solid on the convex side.

Therefore, the straight lines $n\,n'$, $m\,m'$, $v\,v'$, $u\,u'$, are all equal to the height of the hollow cylindric solid, or equal to the distance between the parallel planes and the distance between the lines $n\,n'$, $v\,v'$, equal to the distance between the lines $m\,m'$, $u\,u'$.

To form the common termination between the upper conical and the lower spherical surfaces, let $v\,v'$, $u'u$, represent the concave cylindric surface; and therefore $v\,v'$, $u\,u'$, will represent the opposite circular arcs, which terminate two of the sides of this concavity. Upon this surface draw the line $v''\,u''$, parallel to the circular edge $v\,u$, on the top at the distance $h\,C$, *fig.* 3, and the line $v''u''$ will be the arris now required between the concave conic surface at the top and the concave spheric surface, these two surfaces being as yet to be formed.

To form the remaining and common termination of the concave spherical surface, and the lower or level bed of the stone: — Draw a circular arc on the level surface, underneath parallel to the circular, to the circular edge on the lower edge of the concave cylindric surface, and this line will be the remaining arris required.

The two cylindric surfaces, and the upper plane surface, are entirely cut away; but the intermediate line drawn on the top, and that drawn on each cylindric surface, remain, as well as the outer edge of the lower bed.

To form the intermediate faces of the stone into the two upper and lower conical beds, and into the two apparent concave and convex spherical surfaces: Reduce each side of the solid as near to the required surface as possible, so that all the intermediate parts between the arrises or lines drawn on the former faces may be prominent.

Suppose, then, that we proceed to finish the stone required to be formed in the following order: first, by proceeding with the convex spherical surface; secondly, the upper concave conical surface; thirdly and lastly, the concave spherical surface. Having approached as nearly to the required surfaces as can be done with safety, the upper conical concave surface will be reduced to its ultimate form by cutting away the substance carefully, so that the surface between the two arris-lines may at last coincide with all the points of a straight edge applied perpendicularly to the two arrises.

The convex spherical face will be formed ultimately by cutting the substance of the stone carefully, so that the surface between the arris-line on the top and the circular convex arris-line on the outside of the lower bed may at last agree with all the points of the circular concave edge of the rule made to a portion of the arc A *b c d*, *fig.* 3, of the section of the dome. This circular edged rule must be frequently applied; and in each application the plane of the arc must be perpendicular to the surface, gradually approaching to its required sphericity.

To form the concave surface of the upper bed of the stone, reduce the solid, by carefully cutting parts away, so as at length the surface between the upper arris and the intermediate line drawn on the inside formerly concave may coincide with all the points of a straight edge applied perpendicularly to the upper arris-line from any point of this arris.

The concave spherical surface will be formed in the same manner as the convex spherical surface already supposed to be formed, with this difference, that the circular edge which proves the sphericity, by trial, must be convex instead of being concave. This convex surface lies between the lower arris, terminating the upper conic bed, and the inner arris of the lower bed.

As to the lower bed, it is already formed, being part of the plane surface, formerly one of the ends of the hollow cylinder, in a plane perpendicular to the common axis; and as to the ends forming the vertical joints, they were at first formed in making the hollow cylindric solid; so that one of the stones in the lower course is now finished.

One of the stones in the second course being first formed into the frustrum of a cylindric wedge, as was done with the stone formed for the first course, the several faces which contain this solid are as follow:—$g' r x w$, *fig.* 5, represents the plane truncated sector forming the top, *s t* being the arris-line between the spheric surface on the convex side of *s t*, and the conic surface in the concave side of *s t*; $g r r' g'$, *fig.* 8, the convex cylindric surface, $g'' r r''$ the arris between the convex spheric and the convex conic surfaces, and $r' g g' r'$, *fig.* 9, the concave cylindric surface; $x'' w''$, the arris between the concave spheric surface underneath and the concave conic surface above, the arris-line being drawn upon the lower plane surface; we shall thus have the arris-lines between the spheric and conic surfaces.

The solid being cut as before directed between the arris-lines until the surfaces are duly formed, we shall have also one of the stones in the second course completely prepared for setting.

Perhaps for preparing the stones for the first and second courses, as also the stones near the summit, no better method can be followed than that which we have employed in preparing a stone in each of the two lower courses; yet, as the saving of an expensive material and labor is a desirable object, we shall here show how the waste of stone and the labor of the workman may in a considerable degree be prevented.

PLATE XVIII.—ANOTHER METHOD.

Let *fig.* 1 be the section of the dome, and *fig.* 2 a plan of the same, showing the convex side. Now, as the saving of material will be principally in the stones which constitute the intermediate courses, we shall select, for an example, the fifth stone from the bottom and from the summit. The section of this stone is *a b c d*, *fig.* 1.

Draw *d e* parallel, and *a e* perpendicular, to the base of the dome. Then, instead of first working the sides of the stone, so that the section may be a rectangle, of which two sides are parallel and two perpendicular to the horizon, let it be wrought into the form *a b c d e*, so that the part *d e* may be parallel to the horizon.

Let the section *a b c d e* be transferred to No. 1, at *a b c d e*, and let *f g h i*, No. 1, be the section of the rough stone, out of which the coursing-stone of the dome is to be wrought; the sides of the section of the rough stone having two parallel and two perpendicular faces to the lower bed of the stone. The wrought stone must be selected sufficiently large, so that, when it is reduced to the intended form, all the spherical and conical surfaces must be entire, and thus the arrises will also be entire.

The first operation is to reduce the stone by taking away a triangular prism from the top; the section of which prism is represented by *k l i*, No. 1, so that the surface, of which the section is *d e*, may be a plane surface.

No. 2 is an orthographical projection of the stone, of which the section is *m n o p*, after being thus reduced, *g r s t* representing the plane surface, of which the section *k l*, No. 1, is parallel to the plane of projection. On the plane surface *g r s t*, No. 2, apply a mould *x u v w*, so that the radius of the curved edge *u v* may be equal to the line *d x*, *fig.* 1, *d x* being parallel to the base, meeting the axis in *x*, and that *v u* and *w x* may be straight lines tending to the centre of the arc *u x*; and that the chord of the arc *u x* may be equal to the length of the chord of the upper arris of the stone. Draw lines along *x u*, *u v*, and *w v*, of the mould, and let *v w* be the line drawn by the curved edge *v w* of the mould, *u v* the line drawn by the straight edge *u v* of the mould, and *x w* the line drawn by the straight edge *x w* of the mould.

Take the mould away, and there will remain the three lines, namely, the arc *v w*, and the straight lines *v u* and *w x*, which radiate to the centre. Then *v w* is the upper arris of the stone, and the straight lines *v u* and *w x* are in the planes of the meeting joints of the two adjacent stones, in the same course, to that which is now in the act of working.

The second operation is to work the spherical surface by means of the bevel *e d c*, *fig.* 1, in such a manner, that while the point *d* is upon any point of the arc *v w*, No. 2, the straight edge *d e* may coincide with the plane surface *x u v w*, No. 2, and the curved edge *d c* may coincide with the spherical surface required to be formed, and lastly, that the plane of the bevel *c d e* may be perpendicular to the arris-line *v w*.

The third operation is to find the vertical joints of the stone: these will be formed by means of a common square, of which the right angle is contained by two straight lines, so that when the vertex of the angle of the square is upon any point of the line *v w* or *u x*, No. 2, the inner face of application of the third part must be upon the plane surface *t u v w*, and the edge of application of the thin part upon the vertical joint, and that both edges of application may be perpendicular to the line *v w* or *u x*.

The fourth operation is to form the conical upper bed of the stone by means of the bevel *f g h*, *fig.* 1, so that when this conic surface is wrought to the required form, and the vertex *g* of the angle is applied upon any point of the curve *u v*, No. 2, the curved edge *g h* may then coincide with the spherical surface, and the straight edge *g f* with the conical bed thus formed, the edges *g f* and *g h* being perpendicular to the arris *u x*.

Thus four sides of the stone are now formed, namely, the convex spherical surface, the concave conical surface, and the two vertical joints of the stone. By gauging the spherical surface to its breadth, the under or convex conical surface may be formed by means of the same bevel *f g h*, *fig.* 1, and gauging the sides of the stone which form the joints, namely, the concave and convex conic surfaces which form the upper and lower beds, and the two vertical joints from the spherical convex surface, we shall now be enabled to form the concave spherical surface by means of a slip of wood, of which one edge is formed to the curve of the inside of the section, No. 1, and thus we have formed a stone of the fifth course, as required to be done. In the same manner the stones of every course may be formed.

This method will never require so much stone as the former or first method, nor yet the quantity of workmanship; but it requires greater care in the execution. This last method was used in the construction of the dome of the Hunterian Museum at Glasgow.

To execute a vault, of which both the extrados and intrados are conic surfaces, having a common vertical axis, the solid being equally thick between the conic surfaces, so that in the joint lines those of beds may be horizontal, and those of the headings in vertical planes passing along the axis.

The easiest method of executing this is, to form the beds so that when built they will unite in horizontal planes, and the headings in vertical planes.

Let A B C, *fig.* 3, be a section of the exterior surface, and E F G a section of the interior surface; the lines A B and E F being parallel, as also the lines C B and G F.

In order for the easy application of the bevels, it will be convenient to work the exterior faces of the stones first as plane surfaces; then form the joints by means of a face-mould, and the angles which the joints make with the planes of the faces by means of the bevels, and lastly, run a draught upon each end of the face first wrought, according to the proper curve of the cone.

Let $d$ S $v$ be the exterior line of the plan, D being the centre of all the circles which form the seats of the joint lines in the plan. Divide the semicircular arc $d$ S $v$ into as many equal parts as the number of vertical joints in the semicircumference.

Let there be five stones, for instance, in each quadrant; therefore, if $d$ S and S $v$ be quadrants, divide $d$ S into five equal parts, and let $d\,e$ be the first part. Through the point $e$, draw the radius $f$D. Bisect the arc $d\,e$ in $f$, and draw C$f$ a tangent to the semicircular arc $d$ S $v$ at the point $f$. Bisect each of the arcs between the points of division in the quadrantal arc $d$ S, and the tangents being drawn at each point of bisection, will form the polygonal base C$f\,m\,n\,o\,p$.

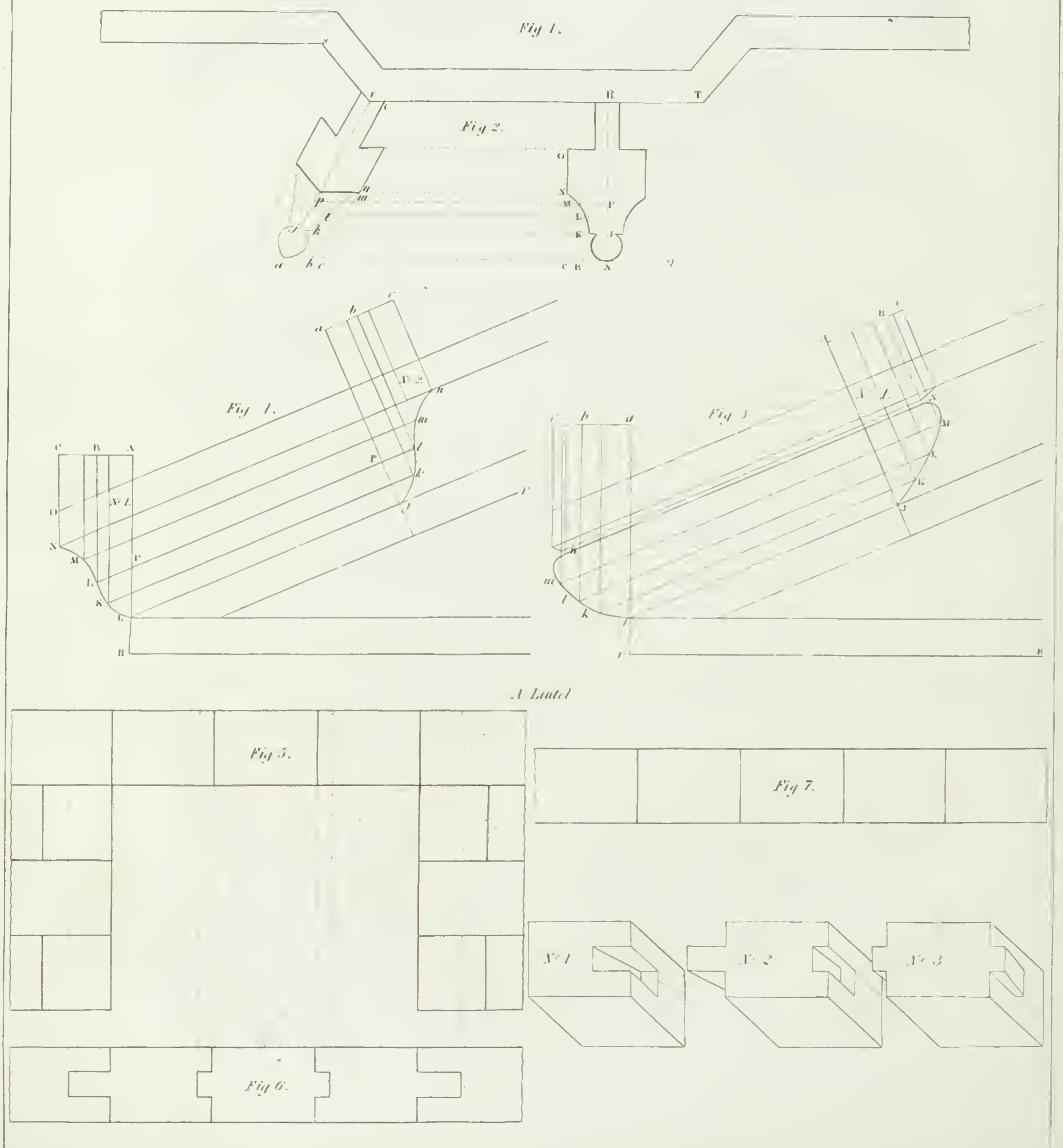
To form the angle of the mitre at the meeting of two heading-joints. In C$f$, or C$f$ produced, take any point $g$, and draw $g\,h$ perpendicular to the diameter A C, meeting A C in the point $h$. Draw $h\,i$ perpendicular to C B, meeting C B in the point $i$. In D C make $h\,k$ equal to $h\,i$ and join $k\,g$; then will the angle D$k\,g$ be the bevel of the mitre.

The sections of each of the stones as they rise being $d\,e'b'$G$'$, $e'i'f'b'$, $i'j'k'f'$, the dimensions of the stones will be found as follows. Through the points $e'$, $i'$, $j'$, draw the straight lines $d'c$, $h'g'$, $k'l'$, intersecting the inner line G F in the points $b'$, $f'$, $k'$. Through $b'$, $f'$, $k'$, draw the lines $a\,b'$, $d'f'$, $h'k'$, perpendicular to A C. Also through the points $e'$, $i'$, $j'$, draw $e'g'$, $i'\,l'$, as also C $c$, which will complete the sections of the stones. The other side, A E F B, of the section exhibits the sections of the stones perpendicular to the intrados and extrados of the lines; the sections of the stones being A E $r$, E $\beta\,t\,r$, $\beta\,y$ V $t$, and the sections of the joints E $r$, $\beta\ t$, $y$ V. To find the curve of the stone at any section, as E $r$ at the point $r$. With the horizontal radius 5 $r$, *fig.* 3, and from the centre 5, describe an arc $r$ 3. From the point 3, draw 3 2 perpendicular to 5 $r$, meeting 5 $r$ in 2. In 2 $r$ make 2 1 equal to the nearest distance between the point 2 and the line A B. From some point found in the line 5 $r$, describe an arc 1 3, and the arc 1 3 will be the curvature of the top of the stone at the joint. This is shown at *fig.* 4.

*Figs.* 5 and 6 exhibit another method of finding the curve at the joint, by means of the radius of curvature.

Pl 19.

# RAKING MOULDINGS.




H. W. Wilson Sc.

## SECTION XIII. — The Manner of finding the Sections of Raking Mouldings.

To find the raking mouldings of a canted bow-window, with munnions and transoms.

Let the plan of the window be *fig.* 1, *Plate* XIX., consisting of three sides, the middle one being parallel to the walls, and the other two at an angle of 135 degrees each, with the middle face of the window.

Also, let *r a* Q, *fig.* 2, be a horizontal section of one of the angles, No. 1 being a right section of one of the munnions, the same as the right section of the transom-sill or lintel, and let *a r*, No. 2, be the line of mitre corresponding to A R, No. 1, A R being perpendicular to *a* Q.

In order to find the right section, No. 2, of the angular munnion. In the curves of the given section, No. 1, draw lines through a sufficient number of points perpendicular to *a* Q, and draw *a c* perpendicular to *a r;* transfer the points B C from A, No. 1, made by the perpendiculars to No. 2; from *a* to *c* upon *a c*, and from *a* to *b* through the points in *a c*, draw lines parallel to *a r*, to intersect the corresponding lines parallel to Q *a* from the assumed points K, L, M, N, in the curves, No. 1, and through these points trace the curves which will form one side of the section No. 2; repeat the same operation on the other side, and we shall have the complete section required.

*Figs.* 3 and 4, No. 1, is the right section of the raking moulding on a pediment, which, if supposed to be given, the section No. 2 may be found, as that at No. 2, from No. 1, *fig.* 2; but in this case No. 2 is generally that which is given, and the section No. 1 is traced therefrom.

In all these cases of raking mouldings, draw *a c* perpendicular to *a r*, the line of mitre. To find any point *m*, take the point M in the section No. 1, and draw M B perpendicular to A C, Nos. 1 and 2, meeting A C in B, and draw M *m* parallel to R *r*. Make *a b* equal to A B, and draw *b m* parallel to *a j*, and *m* will be a point in the curve. In the same manner will be found the points *j*, *k*, *l*, *n*, No. 2, from the points J, K, L, N, No. 1; and hence the section No. 2 may be traced from No. 1.

*Fig.* 4 is described in the same manner as *fig.* 3.

SECTION XIV. — Construction of a Lintel, or an Architrave, in three or more Parts, over an Opening, and the Steps of a Stair over an Area.

On the method of building a lintel, or architrave, with several stones, so that the soffit and top of the lintel, or architrave, may be level; and that the connecting joints of the course may appear to be vertical in the front and rear of the lintel, or architrave.

A lintel, or architrave, is frequently formed in several stones, from the difficulty of procuring one of sufficient length. The method of doing this is founded upon the principle of arching, the arch being concealed within the thickness of the stones.

*Fig.* 5, *Plate* XIX., represents the upper part of an aperture, lintelled as specified in the contents of this section; the centre of the radiating joints being the vertex of an equilateral triangle.

*Fig.* 6 represents the top of the lintel, exhibiting the thickness of the radiating joints, and the thickness of the square joints on each side of the concealed arch.

*Fig.* 7 represents the soffit of the lintel, exhibiting the joint lines perpendicular to the two edges, as the radiating as well as the vertical joints all terminate in these lines.

No. 1 exhibits the first abutment-stone over the pier; No. 2, the first stone of the lintel; No. 3, the second stone, which forms the key; the two remaining stones are the same as the first stone of the lintel and the abutment-stone, being placed in reverse order.

The three stones here exhibited show the manner of indenting the stones so as to form a series of wedges; and in order to regulate the soffit, the radiations are stopped at half their height.

*Fig.* 1, *Plate* XXV., exhibits the method of constructing an architrave over columns when the stone is not of sufficient length to reach the two columns. No. 1, plan of the upper horizontal side of the architrave, exhibiting a chain-bar of wrought-iron, with collars let in flush with the top bed, the sockets being filled with melted lead round the collars.

In the plan and elevation, the same letters express different sides of the same parts; thus, in the elevation, *fig.* 1, the letter A is written upon the part expressing the vertical face of the stone, over the angular column; and A, on the plan No. 1, expresses the horizontal side or bed of the same stone. The letter B, on the elevation *fig.* 1, represents the vertical face of the middle stone of the

Pl. 20.

# GOTHIC ARCHES,

Fig. 1.

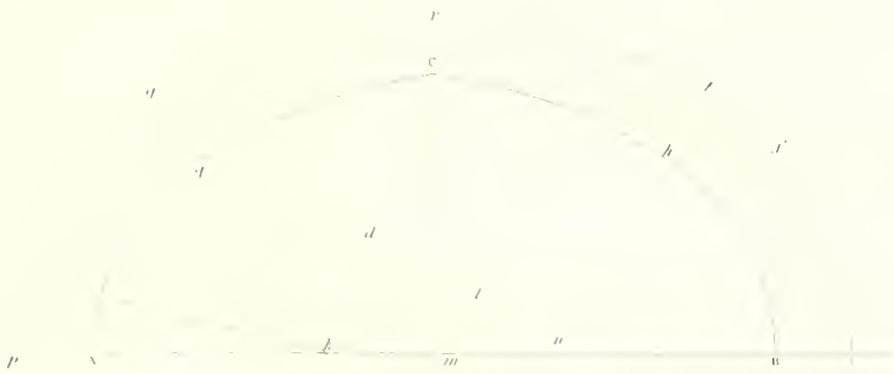



Fig. 2.

Fig. 3.

Fig. 4.

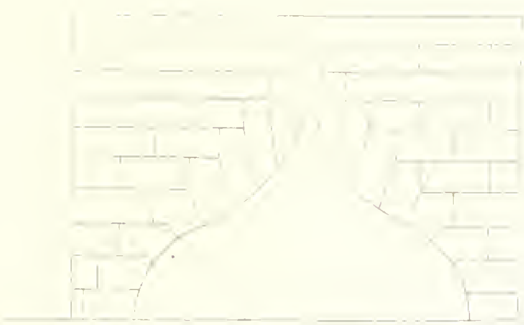
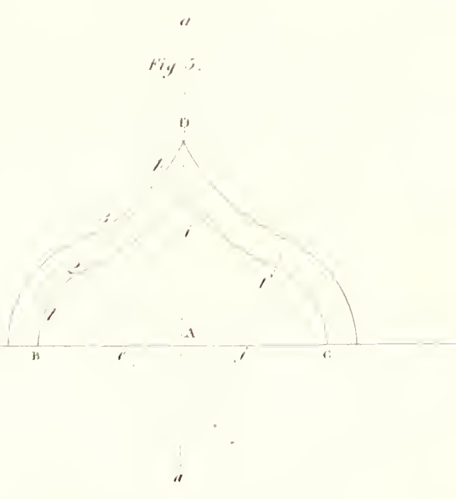


Fig. 5.

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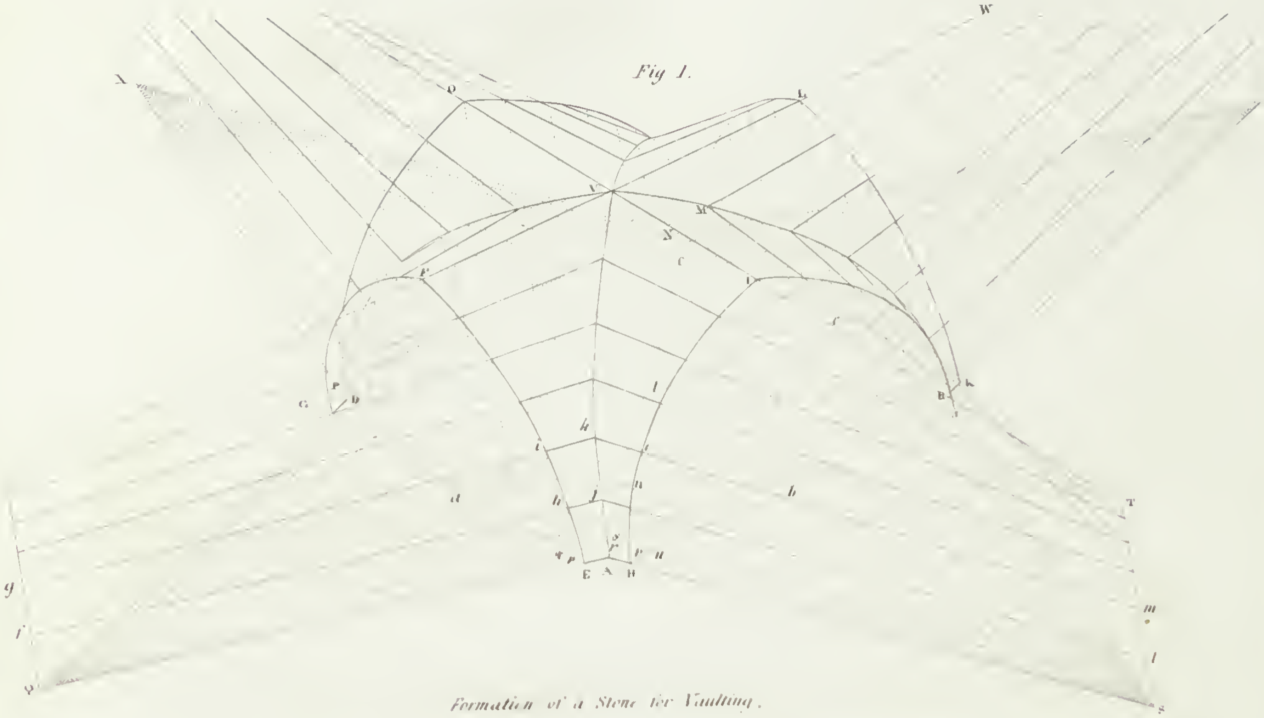
Pl 21.

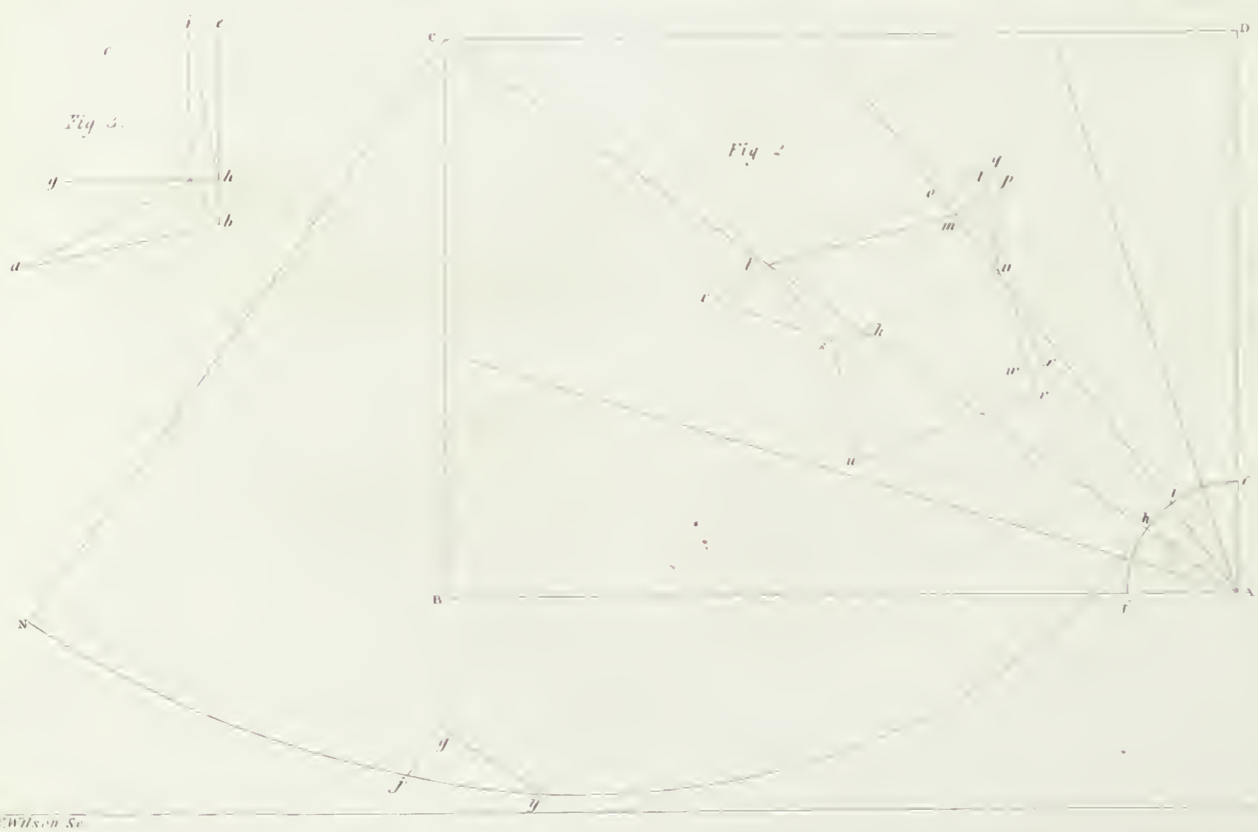
# GOTHIC CEILING.

Fig 1.



Formation of a Stone for Vaulting.

Fig 3. Fig 2.



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Pl 22.

## GRECIAN WALLS.

## ROMAN WALLS.

*Fig 1.*

*Fig 2.*

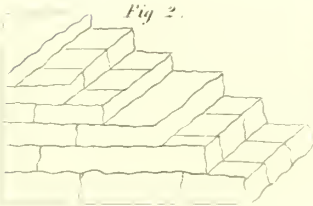


*Fig 3.*

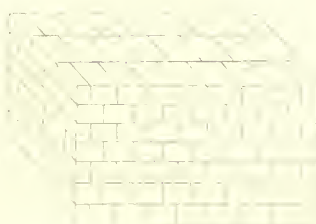


*Fig 4.*

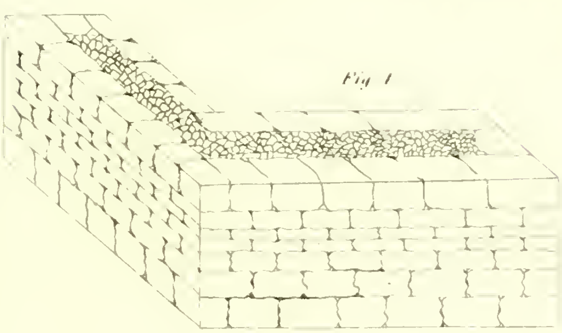


*Fig 5.*

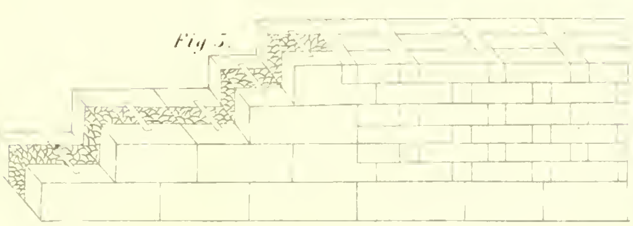


*Fig 6.*

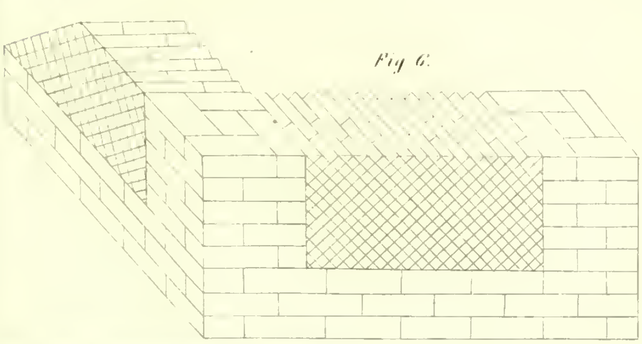


*Fig 7.*

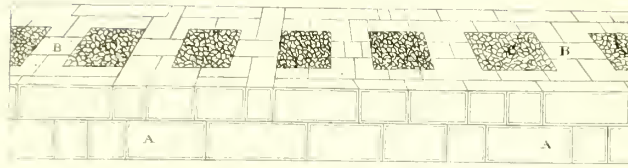



*Fig 8.*

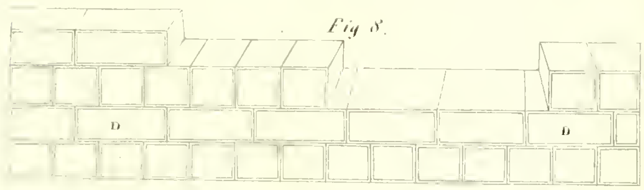



*Fig 9.*

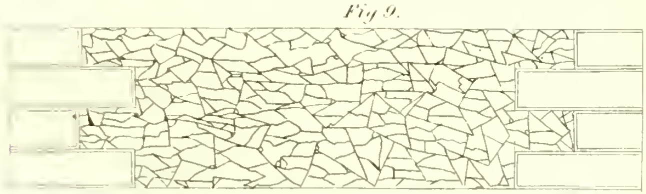


*Fig 10.*

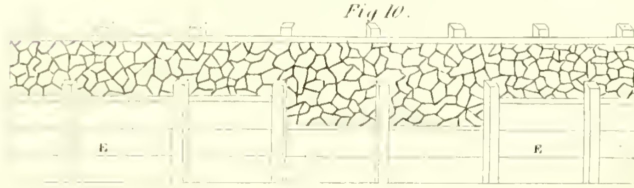



*Fig 11.*

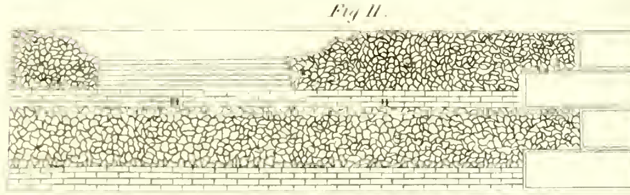



*Fig 12.*

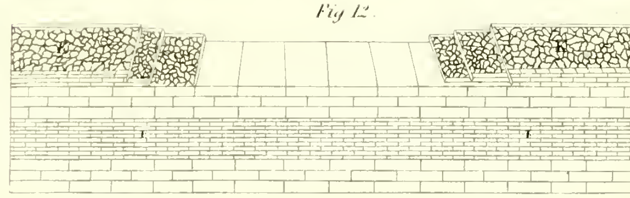
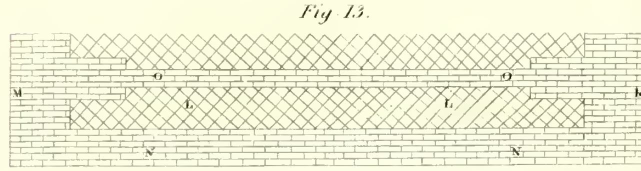



*Fig 13.*

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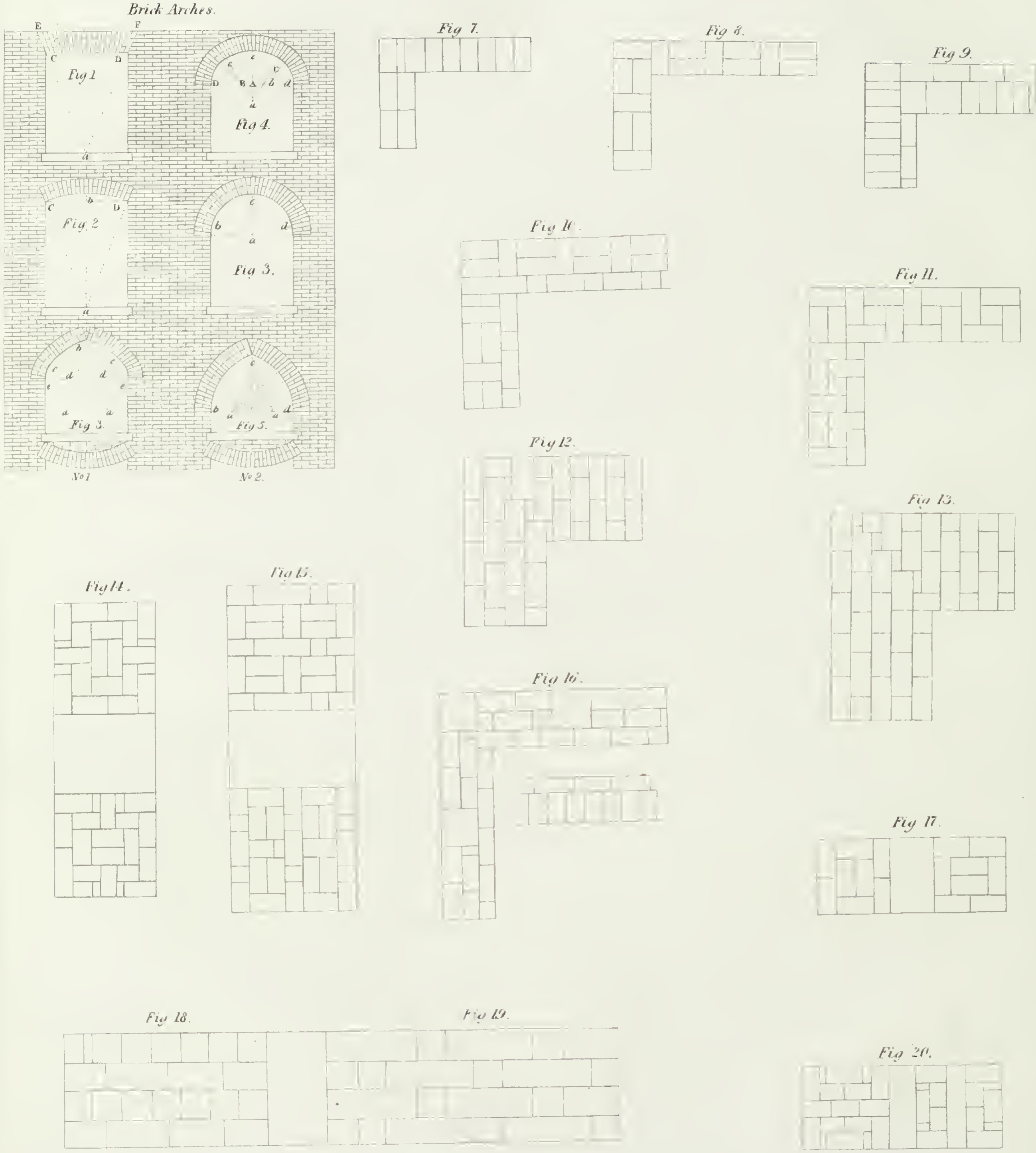
Pl 23.

# BRICK BONDS.

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architrave; and B, on the plan, represents the bed of the middle stone. The letter C, on the elevation, represents the vertical face of the stone over the second column; and C represents the upper horizontal surface or bed. The stones A and C serve as abutments to the middle stone B, which is let in in the manner of a keystone, and therefore acts as a wedge. In order to lessen the effect of the pressure of the inclined sides from forcing the columns to a greater distance, the joint *o n n m m* has two horizontal wedges, *n n*, *m m*, which will prevent the middle part from descending.

D exhibits a stone in the act of setting, and is let down by means of a lewis; a brick arch is exhibited over the architrave, in order to discharge the weight from above, and is resisted by the abutments at the ends. The lateral pressure of the brick arch, and of the stone B, is entirely counteracted by means of the chain-bar, of which the top is represented in No. 1.

No. 3 exhibits a section of the work, *z* being a section of the arch in the middle, and *y* shows the void between. The right section through the middle of the arch between the columns is the same as shown at *z y w*.

No. 2 exhibits the manner of cutting the joints of the stones over the column, *g* and *w* being the steps of the socket, and *u u u* the square part of the joint.

On the construction of stairs over an area to an entrance door.

Stairs of this description, which consist of one flight, must either be supported upon a solid foundation raised from the ground; or, if over a hollow, the steps must be supported upon a brick arch, or otherwise, by working the soffits in the form of a concave curve.

F F represents the abutments of the columns; E, the steps; G, the cantæ, as projecting from the wall, to support the architrave-stone D.

Since the joints should always be perpendicular to the curve, they must all tend to the centre of the circle which forms the soffit; and since the steps should rest firmly upon one another, they ought to rest upon a horizontal surface. To accomplish these ends, every joint between two steps ought to consist of two surfaces, one horizontal, and the other part a plane, radiating to the axis of the cylinder, of which the soffit of the steps is the curved surface.

*Fig.* 5, *Plate* XV., is the plan, *fig.* 1, the elevation, of a semicircular arched door-way, built of wrought stone, with steps, and *fig.* 2, a section of the same; *a b* is the curve-line, representing a section of the soffits. The joints are here drawn to the centre *c* of the arc *a b*.

In this case, where there are no brick arches below, the joints should be plugged. *Fig.* 4 exhibits a section of the steps, showing the plugs, one in each end perpendicular to the surface of the joint.

## SECTION XV. — Construction of the Stones for Gothic Vaults, in Rectangular Compartments upon the Plan.

### GROINED ARCHES SPRINGING FROM POLYGONAL PILLARS.

To execute a ribbed-groined ceiling in severies, upon a rectangular plan, so that the ribs may spring from points in the quadrantal arc of a circle, of which the centres are in the angular points of the plan, and to terminate in a horizontal ridge parallel to the sides of the severies, and in a vertical plane, bisecting each side of the plan.

Let S T V W, *Plate* XXVI., *fig.* 1, be a portion of the plan consisting of two severies, S T U X, X U V W, the points S, T, U, V, W, X, being the points into which the axes of the pillars are projected.

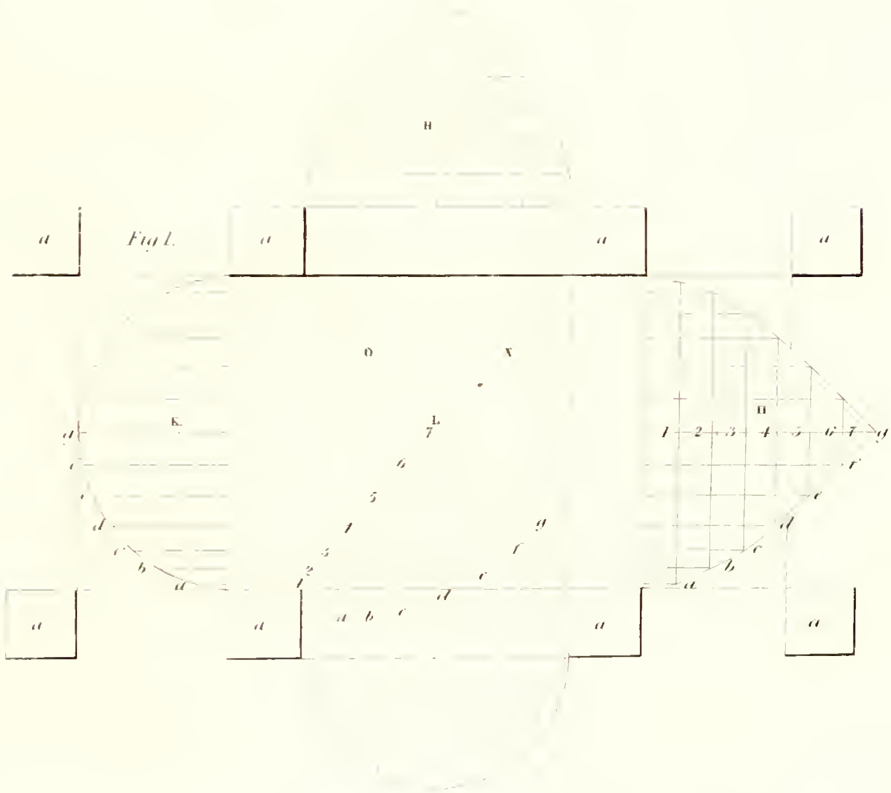
Bisect V W by the perpendicular *r* L, and bisect V U by the perpendicular *p* L. Draw the straight lines *u q*, *v* L, *w m*, *x n*, *y o*, radiating from V to meet the ridge lines *r* L and L *p* in the points *r*, *q*, L, *m*, *n*, *o*, and the arc *t z*, described from *v* in the points *u*, *v*, *w*, *x*, *y*, and these lines will be the plans of the ribs for one quarter of a severy.

Suppose now the rib over *t r* to be given, and let this rib be *fig.* 2, which is here made double. The half *a b c* is the rib which stands upon *r t*, the curve *b c*, *fig.* 2, and the plans, *t r*, *u q*, *v* L, *w m*, *x n*, *y o*, *z p*, *fig.* 1, of the ribs are given by the architect in the plan and sections of the work; it is the workman's province to find the curvature of the ribs, and the formation of the stones for the ceiling.

For this purpose, we shall suppose that the chords which are formed by the joints in the intrados upon the meeting of the rib over *t r* to be equal; therefore, divide the curve *b c*, *fig.* 2, into equal parts, so as to admit of vault-stones of a convenient size.

From the points 1, 2, 3, &c., *fig.* 2, in the arc *b c*, draw lines perpendicular to *a b*, the base of the rib. Transfer the parts of the line *a b* to *r t*, *fig.* 1, and let A be one of the points representing *e*, *fig.* 3. In *fig.* 1, draw *u t*, and produce *u t* and L *r* to meet each other in the point 3. Draw the straight line A B radiating to the point 2, to meet the plan *u q* in B. Join *u v*, and produce *v u* and L *r* to meet in 3, and draw the straight line B C radiating from 2, to meet the plan *v* L in C. Join *v w*, and produce *v w* and L *p* to meet each other in H. Draw C D radiating to the point H, to meet *w m* in D. Join *w x*, and produce *w x* and L *p* to meet each other in 1, and draw D E radiating to the point I, to meet *x n* in E. Find the points F and G in the same manner as each of

# GROINED ARCHES AND VAULTING.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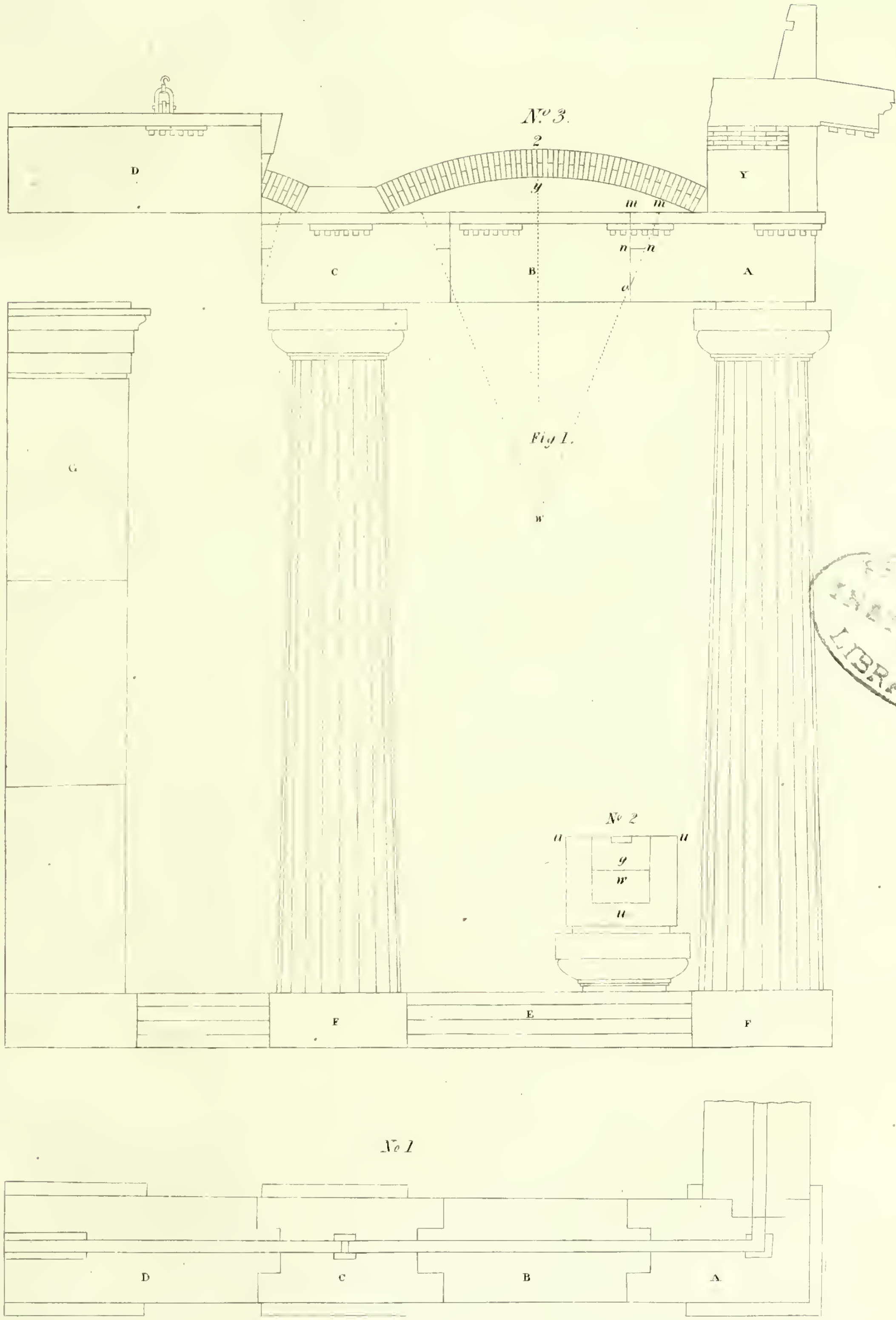
Pl. 25.

# DORIC COLUMNS AND ARCHITRAVE.



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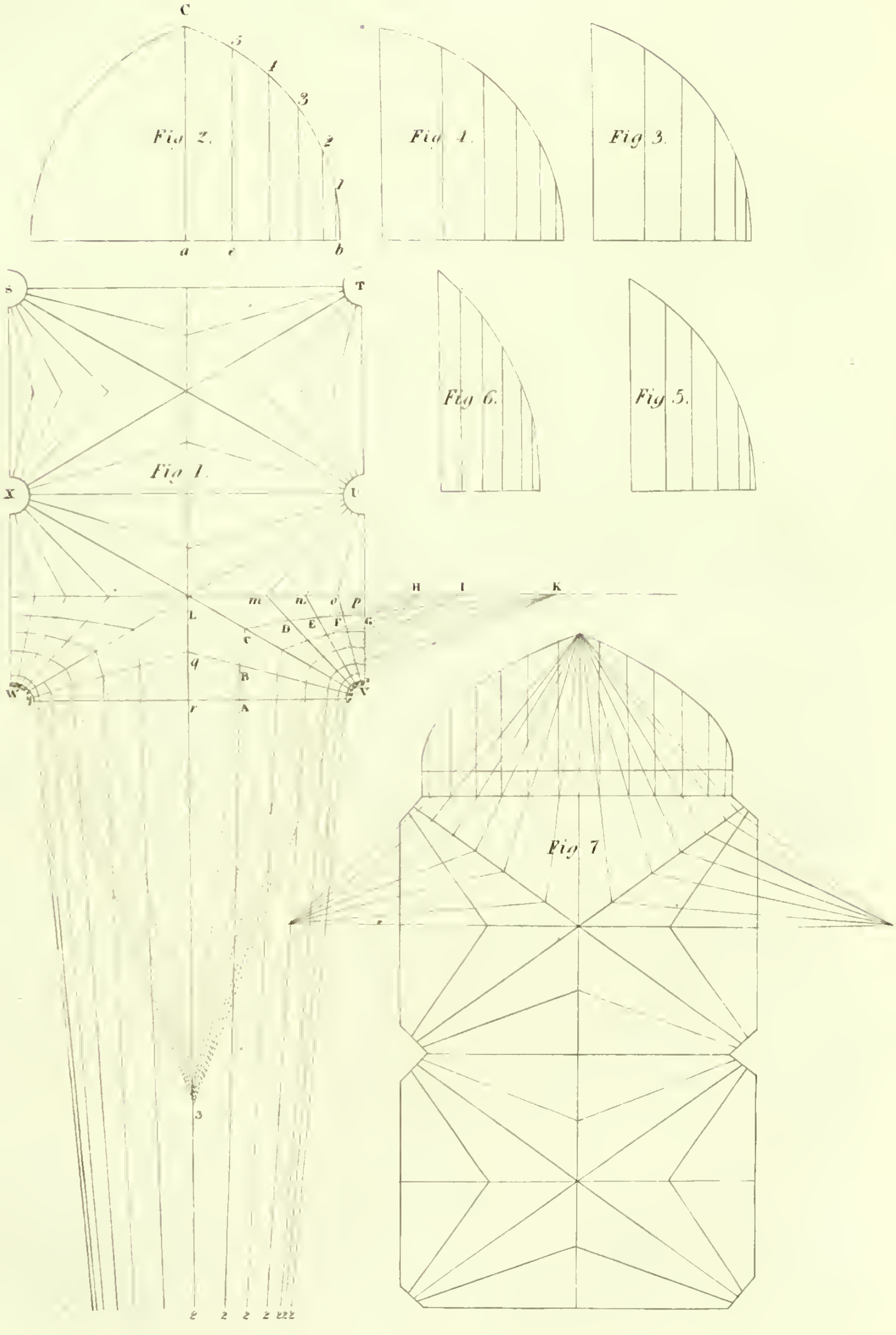
# GOTHIC VAULTING.

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the points B, C, D, E, have been found, and the compound line A B C D E F G will be the line of joints corresponding to the point 5, *fig.* 2. Find the lines corresponding to the other joints in the same manner. Transfer the divisions in the line *u q* to the base line of *fig.* 3, and draw lines perpendicular to the base as ordinates. Transfer the ordinates of *fig.* 2 to their corresponding ordinate in *fig.* 3, and draw the curves which will complete the inner edge of the rib, *fig.* 3. In the same manner find the curve of the ribs, *figs.* 4, 5, 6, &c., which stand over the lines *v* L, *w m*, *x n*, &c.

*Fig.* 7 exhibits a part of the plan of a groin-ceiling, consisting of two severies when the plans of the piers are squares, of which the angular points terminate in the sides of the plan of each severy, and then we have only to find the diagonal ribs and those upon the narrow side of the severy. It must, however, be observed, both in *figs.* 1 and 7, that only one of the curves which belong to arches of the two sides of a severy can be given; the other must be found in the same manner as the curves of the intermediate ribs. In *fig.* 7 the plan of the joints has only two points of convergence, which are found by producing the side of the square which forms the plan of the pillars, and the plan of the ridge-lines, till they meet each other.

We shall now proceed towards the formation of the stones of the vaulting.

*Plate* XXI., *Fig.* 2. Let A B C D be the plan of one quarter of a severy, and let *h* C and *i f* be the seats of two adjacent ribs, and let *h y j* N C be the rib which stands upon *h* C, and let *k l m n* be the plan of the soffit of a stone. Perpendicular to *h* C draw *k y* and *l j*, and draw *y g* parallel to *h* C. Produce *n k* to *s* and *n m* to *o*. Draw *l o* and *l s* respectively parallel to *s n* and *n m*. Draw *l r* perpendicular to *l s*; make *l r* equal to *g j* and join *s r*. Draw *l u* perpendicular to *s n*; and from *s*, with the radius *s r*, describe an arc meeting *l u* in the point *u*. Draw *u v* and *n v* respectively parallel to *s n* and *s u*. Perpendicular to *n o* draw *o q* and *m p*. Make *o q* and *m p* each equal to *g j*, and join *n p* and *n q*. Draw *p t* perpendicular to *n q*, meeting *n q* in the point *t*. To form the winding surface of the intrados, first work the soffit as a plane surface; on the plane surface describe the figure *u s n v*. Make *n w* equal to *n t*.

In *fig.* 3 make the angle *a b c* equal to *s n o*, *fig.* 2, and make the angle *c b e*, *fig.* 3, equal to *o n q*. Having the two legs *c b a*, *c b e*, of a right-angled trehedral, find the angle *g h i*, which the hypothenuse makes with the leg *c b e*. Secondly, form the bed of the stone to make an angle at the arris-line *n v* with the surface *u s n v*, equal to the angle *g h i*, *fig.* 3. Draw *w x* upon the end of the stone thus formed perpendicular to *n w*, and make *w x* equal to *t p*, and on the end of the stone draw *n x*. Join *k u*; then the four points *n*, *k*, *u*, *x*, are the four angular points of the soffit of the stone. The other end of the stone will be formed in a similar manner.

On the nature and construction of Gothic ceilings.

Let A, B, C, D, *Plate* XXI., *fig.* 1, be the springing-points, A C and B D the plans of the groins disposed in the vertices of the angle of a rectangle, their planes bisecting each other in the point *e;* also let Q U and S X, passing through the point *e*, and bisecting the angles A *e* B, B *e* C, C *e* D, D *e* A, be the plans of the ridges of the Gothic arches, and let A E, A H, B J, B K, C M, C N, D P, D G, be the springing-lines of the Gothic ceiling.

Moreover, let the four straight lines E G, H J, K M, N P, at right angles to Q U and S X, be the plans of four right sections to each wing of the groined vault.

From the point *k* as a centre, with the radius *k p*, describe the arc *h g;* and let the springing-lines A E, D G, A H, J B, &c., be such as to meet respectively in the points Q, S, &c.

To construct the ribs which are at right angles to the ridge-lines, and of which their plans are E G, H J, &c. Let us suppose that the given rib is E F G, standing upon E G as its plan. Prolong A E and D G to meet each other in the point Q. Divide the half-curve E F of the arch into as many equal parts as the number of courses is intended to be in the ceiling on each side of the ridge-line of the intrados of the arch; let us suppose that this number is six, and that *h* is the first point of division from the bottom point E of the rib, the succession of parts being E *h*, *h i*, &c. From the points *h*, *i*, &c., draw the straight lines *h p*, *i q*, &c., perpendicularly to E G, meeting E G in the points *p*, *q*, &c. Through the joints *p*, *q*, &c., draw from the point Q the lines Q *r*, Q *s*, &c., meeting A C, the plan of the groin, in the points *r*, *s*, &c., and perpendicularly to A C draw the straight lines *r j*, *s k*, &c. Make *r j*, *s k*, &c., each respectively equal to *p h*, *q i*, &c.; through the points A, *j*, *k*, &c., draw the curve A *j k* V for one half of the curve of the groin rib; the other half is symmetrical, and therefore the same curve in a reversed order.

To find the rib H I J. Prolong A H and B J to meet each other in the point S, and draw the lines *r* S, *s* S, &c., intersecting H J in the points *t*, *u*, &c. Draw *t n*, *u o*, &c., perpendicular to H J, and make *t n*, *u o*, &c., respectively equal to *p h*, *q i*, &c. Through the points H, *n*, *o*, &c., draw the curve H I, and H I will be the curve of one half of the arch over the line H J for the plan.

Hence we see that the lines *j h*, *k i*, &c., prolonged, will meet the line Q R perpendicular to the plane A B C D in the points *f*, *g*, &c., at the same heights, Q *f*, Q *g*, &c., as *p h*, *p i*, &c., of the heights of the ordinates of the given rib. Since both sides are symmetrical, one description will serve each of them.

To describe a Gothic isosceles arch to any width, height, and to a given vertical angle.

*Plate* XX. Let A B, *fig.* 1, be the span or width of the arch; *m* C, perpendicular to A B, from the middle point *m*, the height; and *e* C *f* the vertical angle given by the tangents C *e* and C *f*, making equal angles with the line of height, *m* C.

In this example, the points *e* and *f*, the lower extremities of the tangents, are regulated by erecting A *e* and B *f*, each perpendicular to A B, and making each equal to three fourths of the height-line, *m* C.

From the point A, towards B, make A *k* equal to A *e* or B *f*, that is, equal to three fourths *m* C; and from the point C, the vertex of the arch, draw C *e* perpendicular to C *i*. In C *i* take C *l*, equal to A *k*, and join *k l*; bisect *k l* by a perpendicular, *d i* meeting C *i* in the point *i*; join *i k*, and produce *i k* to *g*.

From the point *i*, with the radius *i* C, describe an arc C *g*, meeting the line *i g* in the point *g*, and from the point *k*, with the radius *k g*, describe an arc *g* A, and A *g* C will be the one half of the intrados of the Gothic arch required.

Produce C *m* to meet *k i* in the point *n*, and in A B make *m u* equal to *m k*, join *n u*, and prolong *n u* to *t*, and *u n* to *o*. Make *n o* equal to *n i*. From the centre *o*, with the radius *o* C, describe the arc C *h*, meeting *u t* in the point *h*, and from *u*, with the radius *u h*, describe the arc *h* B, and B *h* C will be the other half of the intrados.

Upon A B, prolonged both ways to *p* and *s*, make A *p* and B *s* each equal to the length of each one of the arch-stones in a direction of a radius.

From the point *k* as a centre, with the radius *k p*, describe the arc *p g*, and from the point *i*, with the radius *i g*, describe the arc *g r*, and *p g r* will be half of the extrados of the arch.

In the same manner will be formed *s t r*, the other half of the extrados. The arch-stones are divided upon the dotted line in the middle into equal parts, and the point lines are drawn by the centres of the intrados and extrados of the arch.



REMARK.

When the height of the arch is equal to or greater than half the span, and when it is not necessary that the vertical angle should be given, the curves of the intrados and extrados on the one side may be described from the same centre, as also those of the other side from another centre.

The most easy Gothic arch to describe is that of which the height of the intrados is such as to be the perpendicular of an equilateral triangle, described upon the spanning-line as a base; such is *fig.* 2, and these centres are the points to which the radiating joints must tend.

Gothic arches seldom exceed in height the perpendicular of the equilateral triangle inscribed in the intrados of the aperture ; but when the arch is surmounted, and the height less than the perpendicular of the equilateral triangle made upon the base, draw a straight line from one extremity of the base to the vertex, and bisect this line by a perpendicular. From the point where the perpendicular meets the base of the arch, and with a radius equal to the distance between this point and the extremity of the base joined to the vertex, describe an arc between the two points, joined by the straight line, and the curve which forms one side of the intrados will be complete. In the same manner will be formed the curve on the other side (see *fig*. 3), so that by only two centres the whole of the intrados will be formed.

*Figs*. 4 and 5 show the method of erecting another form of Gothic arches.

*Fig*. 4 represents the manner of inserting the stone in a straight wall, so as to form a circular pointed arch.

*Fig*. 5 shows the manner of forming the same arch. Let B C be the base-line of the arch ; find the centre A, of B C ; at A erect the perpendicular A D, the intended height of the arch ; find *i*, the centre of A D, produce A D to *a*, and make A *a* equal to A *i ;* join B D, and divide it into five equal parts at 1, 2, 3, 4, 5. Draw the line *a* 2 through the point *e*, produce *a* 2 to *g*, make *g* 2 equal to *a* 2, and *e* and *g* will be the radiating points. From the point *e*, with the radius *e* B, describe the arc B 2, and from the point *g*, with the radius *g* D, describe the arc D 2, and B 2 will be the intrados of one portion of the arch, and D 2 the extrados of the other corresponding portion of the arch. The extrados and intrados of the remaining side may be found in the same manner.

## CHAPTER V.

### SECTION I.— Ancient Walls.

The ancients used several kinds of walls, in which more or less masonry was always introduced. They had their *incertain*, or *inserted* walls, and also their *reticulated* walls.

The uncertain or irregular walls are those where the stones are laid with their natural dimensions, and their figure and size of course uncertain. *Plate* XXII., *fig*. 2. The materials rest firmly one upon another, and are interwoven together, so that they are much stronger than the reticulated, though not so handsome. In this kind of wall the courses were always level; but the upright joints were not ranged regularly or perpendicularly to each other in alternate courses, nor in any other respect correspondently; but uncertainly, according to the size of the bricks or stones employed. Thus our bricks are arranged in ordinary walls, in which all that is regarded is, that the upright joints in two adjoining courses do not coincide. Walls of both sorts are formed of very small pieces, that they may have a sufficiency of, or be saturated with, mortar, which adds greatly to their solidity.

To saturate or fill up a wall with mortar, is a practice which ought to be had recourse to in every case where small stones or bricks admit of it. It consists in mixing fresh lime with water, and pouring it, while hot, among the masonry in the body of the wall.

The walls called by the Greeks *isidomum*, *fig*. 3, are those in which all the courses are of equal thickness; and *pseudo-isidomum*, or false, *fig*. 4, when the courses are unequal. Both these walls are firm in proportion to the compactness of the mass, and the solid nature of the stones, so that they do not absorb the moistness of the mortar; and, being situated in regular and level courses, the mortar is prevented from falling, and thus the whole thickness of the wall is united. In the wall called *complecton*, *fig*. 1, the faces of the stones are smooth, the other sides being left as they came from the quarry, and are secured with alternate joints and mortar; the face of this wall was often covered with a coat of plaster. This kind of building, called *diamixton*, *fig*. 5, admits of great expedition, as the artificer can easily raise a case or shell for the two faces of the work, and fill the intermediate space with rubble-work and mortar. Walls of this kind, consequently, consist of three coats; two being the faces and one the rubble core, which is the middle; but the great works of the Greeks were not thus built, for in them the whole intermediate space between the two faces was constructed in the same manner as the faces themselves; and they besides occasionally introduced *diatonos*, or single pieces, extending from one face to the other, to strengthen and bind the wall, *fig.* 5, *a a*. These different methods of uniting the several parts of the masonry of a wall should be well considered by all persons, who are intrusted with works requiring great strength and durability.

If the walls are *isidomoi*, and fastened together with iron, they are properly called *cramped*, *fig.* 5, *c c c*. The net-work structure, *fig.* 6, was much used in ancient Rome, and is beautiful to the sight, but is liable to crack, wherefore no ancient specimens of this kind remain. *Plate* XXII., *fig.* 7, exhibits a species of ancient wall which may be seen at Naples. There are two walls, A A, of square stones, four feet thick; their distance six feet. They are bound together by the transverse walls B B, at the same distance. The cavity C C, left between, s six feet square, and is filled up with rubble-stones and earth.

*Fig.* 8 represents a second kind, built of square stones; this was called *pseudo-isidomum*, D D; to be seen now at Rome in the Temple of Augustus. The third species is the *uncertain*, *fig.* 9; a specimen of which still remains at Palestrina, twenty miles east of Rome. Another kind, *fig.* 10, which may be seen at Sermione, upon the Lake of Garda, is a species of wooden wall, E E, and is called *formæ*; it is stuffed with stone, mortar, &c., at random. The planks being taken away, the wall E E appears, and is called formaceous.

The fifth kind, *fig.* 11, are walls made of cement, G G, composed of rough pebbles out of a river or from a rock; sometimes of shell, as are the walls of Turin in Piedmont. This kind of wall should be bound by three courses of bricks, at the height of two feet, as H H.

The sixth kind is brick-work, *fig.* 12, which, especially in the walls of a city, or extraordinary building, is constructed like the *diamixton*, for the bricks appear, I I, and the rubbish lies concealed in the middle, K K. In the bottom there are six courses of larger bricks; then some less, at the height of three feet; then the walls are bound again with three courses of larger bricks; an example of this kind still remains in the Pantheon, and in the hot-baths built by Diocletian.

The seventh kind, *fig.* 13, is net-work, L L, which Palladio did not approve of, and to insure the strength of which he proposed to erect buttresses at the angles M M, and to place transversely, or lengthwise, six courses of bricks at the bottom, N N, and in the middle three courses, O O, whenever the net-work is raised six feet.

The existing examples of Roman *complecton*, with partial cores of rubble-work or brick, sufficiently prove its durability; but that of the Greeks was worked throughout the whole thickness of the wall in the same manner as the facing of the fronts, as their temples now existing testify.

The thickness of walls should be regulated according to the nature of the materials, and the magnitude of the edifice. Walls of stone may be made one fifth thinner than those of brick; and brick walls in the basement and ground stories of buildings of the first rate should be reticulated with stones, to prevent their splitting; a circumstance which has been too much disregarded by our builders.

## SECTION II. — Construction of Brick Arches.

*Plate* XXIII., *fig.* 1, represents a straight arch or aperture in a brick wall. Describe an isosceles triangle on C D, the width of the arch, as a base-line, whose vertex will be at *a*, produce *a* C to E, and *a* D to F, and E F will be the extrados, and C D the intrados of the arch.

Divide C D and E F into the same number of equal parts, and make the bricks to correspond with these parts.

*Fig.* 2 is a segment arch. Describe an isosceles triangle as in *fig.* 1, and bisect C D in *b;* from the point *a*, with the radius *a* D, describe the arc D *b* C, and with the radius *a* C, produced from the point *a*, describe the extrados, and C *b* D will be the intrados of the arch.

*Fig.* 5 is a semicircular arch; the intrados of which is easily found by making the semidiameter, or one half the width of the arch, the radius of the semicircle *b e* D.

*Fig.* 4 is a semi-elliptical arch, formed from three points. Divide D *d*, the width of the arch, into three equal parts at the points B, *b;* from the centre A of D *d*, erect the perpendicular A *e*, and produce A *e* at pleasure; join B *a*, making B *a* equal to A D; produce *a* B to *c;* at the point B, with the radius B *c*, describe the arc *e d*; join *b a*, and produce *b a* to C; then, with the radius *a c*, at the point *a*, describe the arc *c e* C; and at the point *b*, with the radius *b d*, describe the arc C *d*, and *D e d*, the intrados of the intended arch, will be complete.

*Figs.* 3 and 6 show the construction of Gothic arches on the principles laid down in *Plate* XXXIII., *figs.* 1 and 3.

Nos. 1 and 2 represent the application of inverted arches to the foundations of brick wall. (See *Foundations.*)

## SECTION III. — Bricklaying.

Bricklaying is the art of building with bricks, or the uniting them, by cement or mortar, into various forms for particular purposes.

Bricks are laid in a varied but regular form of connection, or *bond*, as exhibited in *Plate* XXIII. The mode of laying them for an eight-inch walling shown in *fig.* 7 being denominated *English bond*, and *fig.* 8, *Flemish bond*. *Fig.* 9 is English bond in a brick-and-a-half or twelve-inch walling; and *fig.* 10, Flemish bond in the same. *Fig.* 11 represents another method of disposing Flemish bond in a twelve-inch wall. *Fig.* 12, English bond in a sixteen-inch, or a two-brick-thick wall; and *fig.* 13, English bond in a two-and-a-half-brick-thick wall.

*Fig.* 16 is another brick bond, which is admired for its regularity and strength; it is formed of brick and tiles, and connected with this *fig.* is the next course above the tiles, composed of headers.

*Figs.* 14, 15, 17, and 20, represent square courses, in pairs, of Flemish bond. In each pair, if one be the lower course, the other will be the upper course.

The bricks having their lengths in the thickness of the wall are termed *headers*, and those which have their lengths in the length of the wall are *stretchers*. By a *course* in walling is meant the bricks contained between two planes parallel to the horizon, and terminated by the faces of the wall. The thickness is that of one brick with mortar. The mass formed by bricks laid in concentric order, for arches or vaults, is also denominated a *course*.

The disposition of bricks in a wall, of which every alternate course consists of headers, and of which every course between every two nearest courses of headers consists of stretchers, constitutes English bond.

The disposition of bricks in a wall (except at the quoins) of which every alternate brick in the same course is a header, and of which every brick between every two nearest headers is a stretcher, constitutes *Flemish bond*.

It is, therefore, to be understood that *English bond* is a continuation of one kind, throughout, in the same course or horizontal layer, and consists of alternate layers of headers and stretchers, as shown in the plate; the headers serving to bind the wall together in a longitudinal direction, or lengthwise, and the stretchers to prevent the wall splitting crosswise or in a transverse direction. Of these evils the first is the worst, and therefore the most to be feared.

It is supposed that the old English mode of brick-work affords the best security against such accidents, as work of this kind, wheresoever it is so much undermined as to cause a fracture, is not subject to such accidents, but separates, if at all, by breaking through the solid brick, just as if the wall were composed of one piece.

The ancient brick-work of the Romans was of this kind of bond, but the existing specimens are very thick, and have three, or sometimes more, courses of brick laid at certain intervals of the height, stretchers on stretchers, and headers on headers, opposite the return wall, and sometimes at certain distances in the length, forming piers, that bind the wall together in a transverse direction; the intervals between these piers were filled up, and formed panels of rubble or reticulated work; consequently great substance, with strength, were economically obtained.

It will also be understood, *Flemish bond* consists in placing, in the same course, alternate headers and stretchers; a disposition considered as decidedly inferior in every thing but appearance, and even in this the difference is trifling; yet to obtain it strength is sacrificed, and bricks of two qualities are fabricated for the purpose; a firm brick often rubbed, and laid in what the workmen term a putty-joint, for the exterior, and an inferior brick for the interior, substance of the wall; but, as these did not correspond in thickness, the exterior and interior surface of the wall would not be otherwise connected together than by an outside heading brick, here and there continued of its whole length; but, as the work does not admit of this at all times, from the want of agreement in the exterior and interior courses, these headers can be introduced only where such a correspondence takes place, which, sometimes, may not occur for a considerable space.

Walls of this kind consist of two faces of four-inch work, with very little to connect them together, and, what is still worse, the interior face often consists of bad brick, little better than rubbish. The practice of Flemish bond has, notwithstanding, continued in England, from the time of William and Mary, when it was introduced, with many other Dutch fashions, and the workmen are so infatuated with it, that there is now scarcely an instance of the old English bond to be seen.

The frequent splitting of walls into two thicknesses has been attributed to the Flemish bond alone, and various methods have been adopted for its prevention. Some have laid laths, or slips of hoop-iron, occasionally, in the horizontal points between the two courses; others have laid diagonal courses of bricks at certain heights from each other; but the effect of the last method is questionable, as in the diagonal course, by their not being continued to the outside, the bricks are much broken where the strength is required.

The outer appearance is all that can be urged in favor of Flemish bond, and many are of opinion, that, were the English mode executed with the same attention and neatness that is bestowed on the Flemish, it would be considered as equally handsome; and its adoption, in preference, has been strenuously recommended.

In forming English bond, the following rules are to be observed.

1st. Each course is to be formed of headers and stretchers alternately, as *fig.* 1.

2d. Every brick in the same course must be laid in the same direction; but in no instance is a brick to be placed with its whole length along the side of another; but to be so situated that the end of one may reach to the middle of the others which lie contiguous to it, excepting the outside of the stretching course, where three-quarter bricks necessarily occur at the ends, to prevent a continual upright joint in the face-work.

3d. A wall, which crosses at a right angle with another, will have all the bricks of the same level course in the same parallel direction, which completely binds the angles, as shown by *figs.* 7, 9, and 12, *Plate* XXIII.

*Figs.* 14, 15, 17, and 20, are the method of forming square pier, as shown by two courses, one laid on top of the other.

*Fig.* 11, a pair of courses in the English bond, of one foot four inches square, or the length of two bricks.

*Figs.* 15, 17, and 20, are square piers in the Flemish bond; 20 is two and a half brick square; 15 is a pier of three bricks in length to one side; 15 is a pier of the length of three and a half brick square; 17 the length of two bricks square; 14 is a pier of three length square.

*The great principle in the practice of brick-work* lies in the proclivity or certain motion of absolute gravity, caused by a quantity or multiplicity of substances being added or fixed in resistible matter, and which, therefore, naturally tends downwards, according to the weight and power impressed. In bricklaying, this proclivity, chiefly by the yielding mixture of the matter of which mortar is composed, cannot be exactly calculated; because the weight of a brick, or any other substance laid in mortar, will naturally decline according to its substance or quality; particular care should be taken, therefore, that the material be of one regular and equal quality all through the building; and likewise, that the same force should be used to one brick as to another; that is to say, the stroke of the trowel, a thing or point in practice of much more consequence than is generally imagined; for if a brick be actuated by a blow, this will be a much greater pressure upon it than the weight of twenty bricks. It is, also, especially to be remarked, that the many bad effects arising from mortar not being of a proper quality should make masters very cautious in the preparation of it, as well as the certain quality of materials of which it is composed, so that the whole structure may be of equal density, as nearly as can be effected.

Here we may notice a particular which often causes a bulging in large flank walls, especially when they are not properly set off on both sides; that is, the irregular method of laying bricks too high on the front side; this, and building the walls too high on one side, without continuing the other, often causes defects. Notwithstanding, of the two evils, this is the least; and bricks should incline rather to the middle of the wall, that one half of the wall may act as a shore to the other. But even this method, carried too far, will be more injurious than beneficial, because the full width of the wall, in this case, does not take its absolute weight, and the gravity is removed from its first line of direction, which, in all walls, should be perpendicular and united; and it is further to be considered, that, as the walls will have a superincumbent weight to bear, adequate to their full strength, a disjunctive digression is made from the right line of direction; the conjunctive strength becomes divided; and instead of the whole or united support from the wall, its strength is separated in the middle, and takes two lateral bearings of gravity, each insufficient for the purpose; therefore, like a man overloaded either upon his head or shoulders, naturally bends and stoops to the force impressed; in which mutable state the grievances above noticed usually occur.

Another great defect is frequently seen in the fronts of houses, in some of the principal ornaments of brick-work, as arches over windows, &c., and which is too often caused by a want of experience in rubbing the bricks; which is the most difficult part of the branch, and ought to be very well considered. The faults alluded to are the bulging or convexity in which the faces of arches are often found, after the houses are finished, and sometimes a looseness in the key or centre bond. The first of these defects, which appears to be caused by too much weight, is, in reality, no more than a fault in the practice of rubbing the bricks too much off on the insides; for it should be a standing maxim (if you expect them to appear straight under their proper weight) to make them the exact gauge on the inside that they bear upon the front edges; by which means their geometrical bearings are united, and tend to one centre of gravity.

The latter observation, of camber arches not being skewed enough, is an egregious fault; because it takes greatly from the beauty of the arch, and renders it insignificant. The proper method of skewing all camber arches should be one third of their height. For instance, if an arch is nine inches high, it should skew three inches; one of twelve inches, four; one of fifteen, five; and so of all the numbers between those. Observe, in dividing the arch, that the quantity consists of an odd number; by so doing, you will have proper bond, and the key bond in the middle of the arches; in which state it must always be, both for strength and beauty. Likewise observe, that arches are drawn from one centre; the real point of camber arches is obtained from the above proportion. First, divide the height of the arch into three parts; one is the dimension for the skewing; a line drawn from that through the point at the bottom to the perpendicular of the middle arch gives the centre; to which all the rest must be drawn.

## SECTION IV. — Foundations.

### RULES TO BE OBSERVED IN LAYING FOUNDATIONS.

If a projected building is to have cellars, under-ground kitchens, &c., there will commonly be found a sufficient bottom, without any extra process, for a good solid foundation. When this is not the case, the remedies are to dig deeper; or to drive in large stones with the rammer; or by laying in thick pieces of oak, crossing the direction of the wall, and planks of the same timber, wider than the intended wall, and running in the same direction with it. The last one to be spiked firmly to the cross pieces to prevent their sliding, the ground having been previously well rammed under them.

The mode of ascertaining if the ground be solid is by the rammer; if, by striking the ground with this tool, it shake, it must be pierced with a borer, such as is used by well-diggers; and, having found how deep the firm ground is below the surface, you must proceed to remove the loose or soft part, taking care to leave it in the form of steps if it be tapering, that the stones may have a solid bearing, and not be subject to slide, which would be likely to happen if the ground were dug in the form of an inclined plane.

If the ground prove variable, and be hard and soft at different places, the best way is to turn arches from one hard spot to another. Inverted arches have been used for this purpose with great success, by bringing up the piers, which carry the principal weight of the building, to the intended height and thickness, and then turning reversed arches from one pier to another, as shown in *figs.* 3 and 6, *Plate* XXIII., Nos. 1 and 2.

In this case, it is clear that the piers cannot sink without carrying the arches, and consequently the ground on which they lie, with them. This practice is excellent in such cases, and should therefore be general, wherever required.

Where the hard ground is to be found under the apertures only, build your piers on those places, and turn arches from one to the other. In the construction of arches some attention must be paid to the breadth of the insisting pier, whether it will cover the arch or not; for, suppose the middle of the piers to rest over the middle of the summit of the arches, then the narrower the piers, the more curvature the supporting arch ought to have at the apex. When arches of suspension are used, the intrados ought to be clear, so that the arch may have the full effect; but, as already noticed, it will also be requisite here that the ground on which the piers are erected be uniformly hard; for it is better that it should be uniform, though not so hard as might be wished, than to have it unequally so; because, in the first case, the piers would descend uniformly, and the building remain uninjured; but, in the second, a vertical fracture would take place, and endanger the whole structure.

## SECTION V. — Walls, &c.

The foundation being properly prepared, the choice of materials is to be considered. In places much exposed to the weather, the hardest and best bricks must be used, and the softer reserved for in-door work, or for situations less exposed.

If laying bricks in dry weather, and the work is required to be firm, wet your bricks by dipping them in water, or by causing water to be thrown over them before they are used. Few workmen are sufficiently aware of the advantage of wetting bricks; but experience has shown, that works in which this practice has been followed have been much stronger than others, wherein it has been neglected. It is particularly serviceable where work is carried up thin, and putting in grates, furnaces, &c.

In the winter season, so soon as frosty and stormy weather sets in, cover your wall with straw or boards; the first is the best, if well secured, as it protects the top of the wall, in some measure, from frost, which is very prejudicial, particularly when it succeeds much rain; for the rain penetrates to the heart of the wall, and the frost, by converting the water into ice, expands it, and causes the mortar to assume a short and crumbly nature, and altogether destroys its tenacity.

In working up a wall, it is proper not to work more than four or five feet at a time; for, as all walls shrink immediately after building, the part which is first brought up will remain stationary; and when the adjoining part is raised to the same height, a shrinkage or settling will take place, and separate the former from the latter, causing a crack, which will become more and more evident as the work proceeds.

In carrying up any particular part, each side should be sloped off, to receive the bond of the adjoining work on the right and left. Nothing but absolute necessity can justify carrying the work higher, in any particular part, than one scaffold; for, wherever it is so done, the workmen should be answerable for all the evil that may arise from it.

The distinctions of *bond* have already been shown, and we shall now detail them more particularly; referring to *Plate* XXIII., in which the arrangement of bricks of different thickness so as to form *English Bond* is shown, in *figs.* 7, 9, 12, and 13.

*The bond of a wall eight inches* is represented by *fig.* 7. In order to prevent two upright or vertical joints from running over each other, at the end of the first stretcher from the corner place the return stretcher, which is a header, in the face that the stretcher is in below, and occupying half its length; a quarter brick is placed on its side, forming together six inches, and leave a lap two inches for the next header, which lies with its middle upon the middle of the header below, and forms a continuation of the bond. The three-quarter brick, or brick-bat, is called a *closer*.

Another way of effecting this is by laying a three-quarter bat at the corner of the stretching course; for, when the corner head comes to be laid over it, a lap of two inches will be left at the end of the stretchers below for the next header; which, when laid, its middle will come over the joint below the stretcher, and in this manner form the bond.

*In a twelve-inch, or brick-and-half wall*, (*fig.* 9,) the stretching course upon one side is so laid, that the middle of the breadth of the bricks upon the opposite side falls alternately upon the middle of the stretchers and upon the points between the stretchers.

*In a two-brick wall*, (*fig.* 12,) every alternate header, in the heading course, is only half a brick thick on both sides, which breaks the joints in the core of the wall.

*In a two-brick-and-a-half wall*, (*fig.* 13,) the bricks are laid as shown in *fig.* 6.

*Flemish bond*, for an eight-inch wall, is represented in *fig.* 8, wherein two stretchers lie between two headers, the length of the headers and the breadth of the stretchers extending the whole thickness of the wall.

In a brick-and-half Flemish bond, (*fig.* 10,) one side being laid as in *fig.* 2, and the opposite side, with a half-header, opposite to the middle of the stretcher, and the middle of the stretcher opposite the middle of the end of the header.

*Fig.* 5 exhibits another arrangement of Flemish bond, wherein the bricks are disposed alike on both sides of the wall, the tails of the headers being placed contiguous to each other, so as to form square spaces in the core of the wall for half-bricks.

*The face of an upright wall*, English bond, is represented by *fig.* 18, and that of Flemish bond by *fig.* 19.

## SECTION VI. — The Construction of Chimneys.

Many able and scientific men have treated on this subject, but the result of their observations serves only to prove, what is the result of every day's experience, namely, that rarefied air is lighter and less dense than cold air; and that it will ascend with a velocity proportionate to its rarefaction, unless obstructed by other bodies.

Heat, that is generated by the combustion of fuel, exists under two distinct forms; and is known by the names of combustible and radiant heat. Combustible heat partakes of smoke, and is carried off with it into the upper regions; while radiant heat is communicated to opposing bodies in contact with its rays.

It is stated by some, that combustible heat combined with air and smoke exists in the proportion of four to one, compared to radiant heat; but its correct proportion has, perhaps, never been ascertained.

It is, however, certain, that very little radiant heat will escape from a smothered combustion, while a dense smoke will very slowly ascend, and sometimes a portion of it is discharged into the room, and the chimney is pronounced smoky, while the epithets uttered against masons, on such occasions, would be more properly applied to the builders of the fire.

As nature acts by certain laws, we may derive more profitable information by a proper observance of them, than from accidental occurrences.

It is one of the laws of nature that rarefied air ascends, while cold or dense air descends. On the same principle, water discharges itself most copiously through a channel of a uniform and direct surface, on the same inclination. Therefore, channels, that are obstructed by eddies and the discharge of other streams into them, are impeded, and the velocity of the water diminished, so as often to produce what is called back-water for a considerable distance, which, when removed, permits the water to flow with rapidity. Short bends and turnings also present obstacles to the current or flow of water, by which whirlpools are often seen in actual contact with the natural stream. The same observations may be applied to rarefied air or smoke. Hence those flues will carry smoke the best which arise perpendicularly in a uniform direction.

Angles and turnings present obstacles to the progress of the smoke, and should be avoided as much as possible.

Particular attention should be paid to the formation of the throat of the chimney. The dimensions of which should, in no case, exceed the number of square inches contained in a horizontal section of the flue. It has been contended by some that it should be smaller than this, while others have thought that it should be larger; but experience has shown both of these opinions to be erroneous. When the throat is smaller, the frequent rushes of cold air into it, from the opening of doors, &c., sends a gush of smoke into the room, by obstructing the upward current of rarefied air.

When the throats are larger, eddies are formed in them, and the smoke, becoming dense by the steam of the fuel, chokes the flue, and instead of ascending is puffed into the room.

Experience has shown the best construction to be that where the throat contains as many square inches as a section of the flue. If the latter, for instance, is one hundred and forty-four inches, the throat should be four feet long, and three inches wide, nearly on a level with the mantel-bar, or at the top of the opening of the fire-place, and graduated to the regular dimensions of the flue.

As represented in *Plate* XXVII., *figs*. 3 and 4. In this plate, *fig*. 3 shows a side perpendicular section of a chimney; *d*, the partition-wall; *a*, the throat; *b*, the breast; *c*, the height of the graduation to form the regular flue; E, the depth of the jamb; *f*, a trimmer to support the hearth in form of a segment arch.

*Fig*. 4 is the front elevation of *fig*. 3, representing the flues, fire-places, a horizontal section at the hearths, as D E; a section of the flues at the side of the fire-places, I; the core of the chimney, H; the jambs, F; the back of the fire-places, G, with the inclined part of the back.

## SECTION VII. — Fire-Places.

In the selection of materials for the construction of fire-places, those should be preferred which contain the least metallic ingredients. Metals are absorbents of heat, and consequently occasion less heat to be radiated into the room, than materials of a different nature. Soapstone has been found to be one of the best materials for this purpose. It contains but little metallic substance compared to brick; it is capable of a high degree of polish, and of being easily kept clean, by which means the rays of heat are reflected into the room.

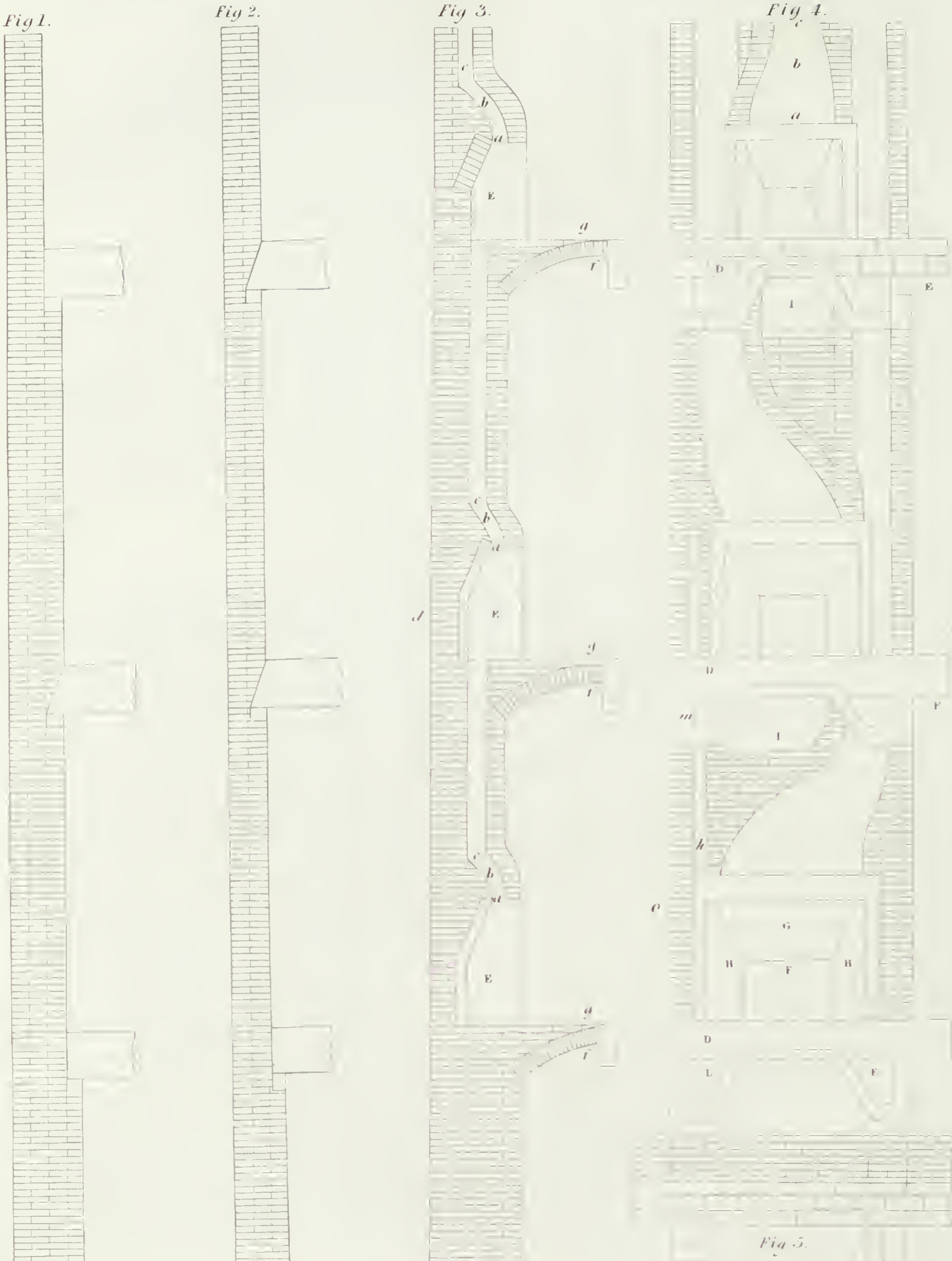
The proportions of a fire-place should in some degree be regulated according to the size of the room which it is intended to warm.

If the room is eighteen feet in length, a fire-place of four feet three inches in width, from jamb to jamb, and three feet in height, where the room is twelve feet in the same direction, or one fourth of the height of the room, may, in general, be considered of suitable proportions. The jambs should form an angle of one hundred and thirty-five degrees with the back. See *Plate* XXVII., *fig*. 4. H, the jamb, the back edge of which should be rabbeted and fitted to a groove in the back, to keep it in its place; F should be set plumb about two fifths of the height of the back, F G; G should be inclined forward to within seven inches of the front line, allowing four inches for the thickness of the breast, and three inches will remain for the passage of the smoke.

*The Communication of Hot Air to Rooms.* —This subject is worthy of attention,

Pl 27.

# CHIMNEY FLUES.

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# CHIMNEY PIECES,

Fig 1

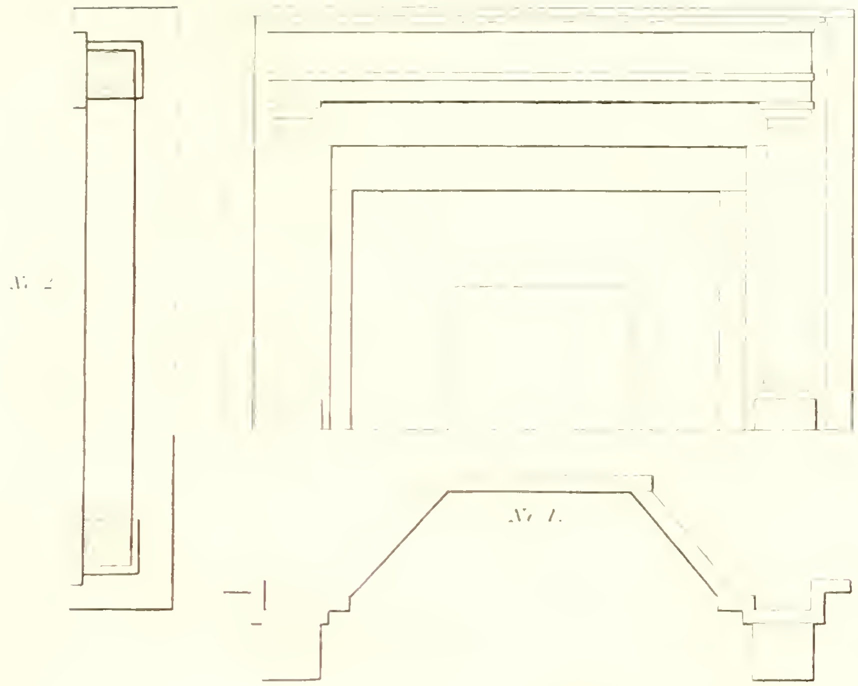
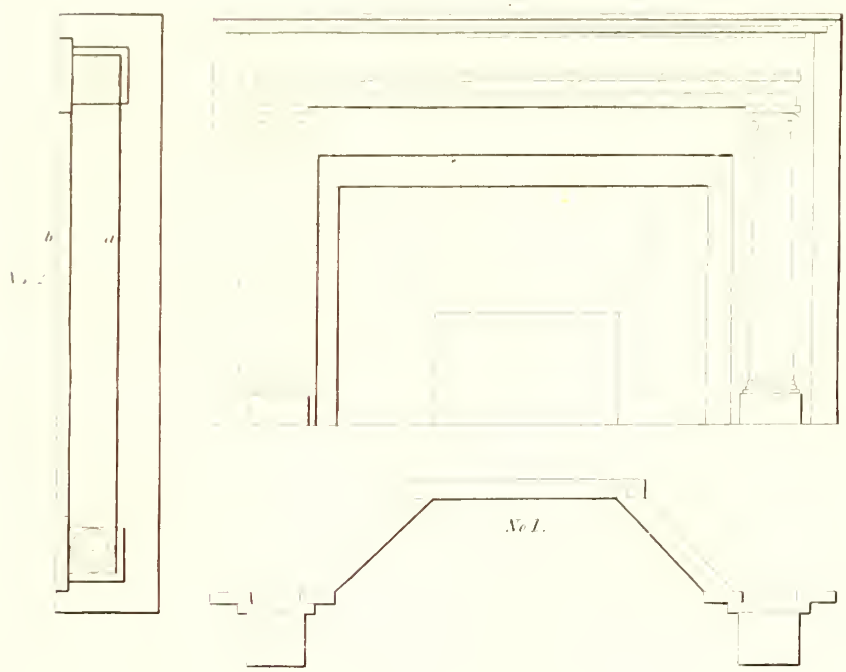



Fig 2

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inasmuch as the temperature of bed-chambers may be regulated by it as well as the danger of fire, and the destructive and fatal effects of charcoal diminished. This improvement may be adapted to common fire-places as well as to grates, and the hot air carried from the first to the upper stories.

A little below the hearth in the first story, a small aperture is opened, of about two inches square, through which to receive fresh air from the outside of the house, into a cavity as large as can with convenience be made between the jambs and the brick which form the wall of the chimney; this cavity should be made tight, with an aperture for the insertion of tubes of copper or tin, which are to be inserted in the aperture with stops or slides, to regulate the quantity of air to be admitted into the room. The air enters about two feet from the floor. By turning the slide, the air is made to ascend into other apartments at pleasure.

*Plate* XXVII., *fig.* 4, L is the generator of rarefied air; *o*, the tube, with a slide at *k*; the ascending pipe should be about four inches square; *m* shows its passage at the hearth.

Chimney-pieces are of various forms, as the fancy or taste of the proprietor may dictate.

In *Plate* XXVIII., *fig.* 1 is a Doric chimney-piece. No. 1, a section of the jambs, back-facing, plinth, and pillars, drawn on a scale of half an inch to a foot; No. 2, the shelf. *Fig.* 2 represents an Ionic chimney-piece; No. 1, a section; No. 2, the shelf; the line *a* shows a projection of the entablature; *b*, the facing under the entablature, drawn on a scale of half an inch to a foot.

## SECTION VIII. — Warming by Steam and Hot Water.

*Perkins's Patent* is upon a principle that will bear investigation. The cooking-range is made with a hollow cast-iron back, to hold from four to five gallons, with copper pipes, introduced one at the bottom and one at the top of this back, extending near three feet from the boiler, of one and a half to two inches calibre; then lead pipe of the same size to be carried to the rooms to be warmed; there lay a coil of about forty feet of pipe; the coil may be inclosed in a chamber to imitate a piece of furniture, thence carried to all the apartments in the house, and returned to the under pipe connected with the hollow back, having the whole tightly closed by soldering; then introduce an aperture at the highest point made convenient for filling with water. When filled, close the aperture, when, by the common use of the range, a current is produced in the water within the pipe, passing from the upper pipe heated, and returning through the lower pipe to renew the revolution. There being no escape for steam, one filling will last a con-

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siderable time without renewing the water. Another, and, as we think, a still better, method of warming houses, or other buildings, by means of heated water, is that of Mr. Dexter, of this city. The following is a description of this method, as exemplified in the house of Mr. S. K. Williams, No. 68 Boylston Street. A chamber of brick-work is built in the cellar, under the front entry, containing three hundred and sixty cubic feet; under, and near the centre, is a grate similar to those used for Bryent and Herman's furnaces, over which is set a copper boiler, holding thirty-two gallons. On one side of the boiler are fifty-four copper tubes, four inches in diameter, and four feet long, set perpendicular, and resting upon a table of brick-work, three and a half feet above the bottom of the cellar, connected by six semi-cylindrical pipes, five feet in length, entering from the boiler, and parallel to each other, and uniting with the boiler at the bottom. The upper ends of the tubes are united with each other in a transverse direction; also, in a semicircular form, a tube connecting with the boiler, near the top, of the same size. The boiler is a cylinder, set upright above the brick-work, four feet in height, and extends nearly to the height of the tubes. In the entry, above, is set a copper vessel, with a lid to shut tight, containing sixteen gallons; a tube three fourths of an inch in diameter enters near the bottom, passing down through the air-chamber into the boiler, for the purpose of filling by a force-pump; a stop-cock is inserted in the vessel at the top, to supply the boiler with cold water. The heated water is drawn from the same boiler for warm baths, and from this air-chamber are funnels, registers, and dampers, entering parlours, entry, &c. To communicate direct heat to the chambers, there is a wooden box, ten by fourteen inches square, set perpendicular against the wall of the entry, passing up to the entry above, or communicating with the rooms by horizontal pipes and registers through the floor. At one side of the grate is a projection of brick-work, inclosing a metallic cylinder, fourteen or fifteen inches in diameter, and about four and one half feet perpendicular, the top of which communicates with a register by a horizontal pipe. Near the bottom of this cylinder is a horizontal branch, to admit the heated air from the large chamber to the small one. The smoke-pipe passes from the grate into the large chamber, entering the perpendicular cylinder through the lower branch, thence, through one side of the cylinder, horizontally to the chimney flue; thus leaving sufficient space to admit the heat from the large chamber into the cylinder, around the smoke-pipe. To admit cold air into the chamber a flue is provided twelve inches in diameter to enter in a downward direction under the front door-steps. This flue passes horizontally under the cellar floor, rises in a perpendicular direction, and enters the chamber near the top. The cold air finds its way through the hot air in the chamber, and becomes sooner rarefied than when entering near the

Pl 29.

# DEXTER'S APPARATUS
## FOR WARMING DWELLING HOUSES.

Fig 1

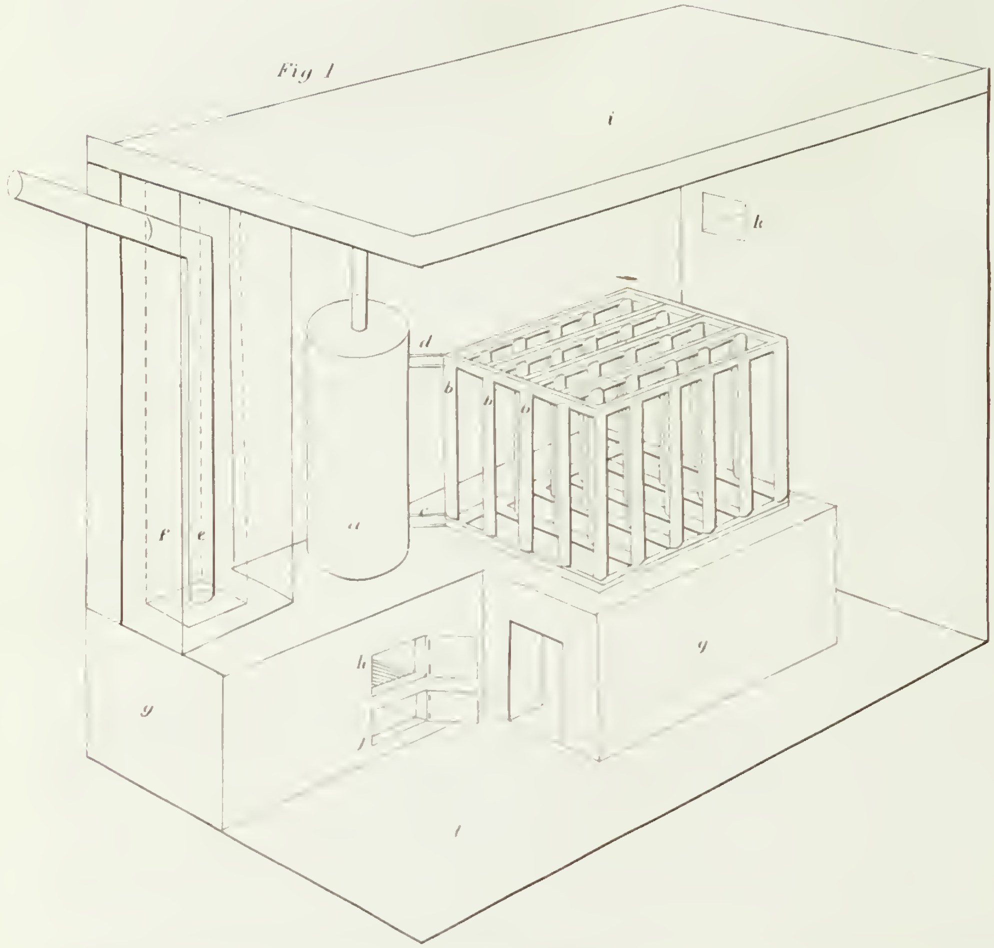
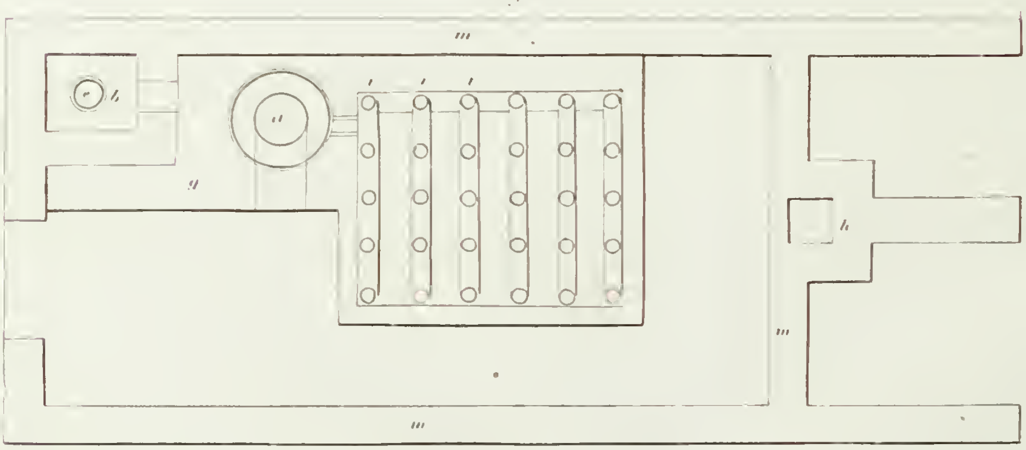



Fig 2.




W. W. Wilson Sc

bottom of the chamber. This experiment by Mr. Dexter is highly successful. It is secure against any eruption from the boiler or pipes, to the injury of the house or its occupants. The rarefied air, thus obtained, produces a sensation similar to that produced by sitting in a room with the windows up in June. In effect, winter is thus changed into summer.

*Dexter's Apparatus for warming Dwelling-houses, &c.* — *Plate* XXIX., *fig.* 1, *a*, the cylinder for heating water; *b*, *b*, &c., perpendicular tubes; *c*, lower pipe, connecting with the boiler; *d*, upper pipe, connected with the boiler at the top; *e*, small chamber, heated by the smoke-pipe, also from the hot-air chambers; *f*, smoke-pipe; *g*, *g*, brick table containing the grates and supporting the apparatus; *h*, fire-grates; *i*, ceiling or floor above the air-chamber; *j*, ash-pit; *k*, cold-air flue; *l*, brick floor.

*Fig.* 2, horizontal section or plan; *a*, boiler; *b*, small chamber; *e*, smoke-flue; *g*, brick table; *h*, cold-air flue; *i*, *i*, &c., semicircular pipes; *m*, *m*, &c., walls of the hot-air chamber.

*Blaney's Water Furnace*, for warming the air in dwelling-houses through the medium of hot water. The air is conducted from an air-chamber, through pipes and registers, to the several apartments. The chamber is made of brick, containing about five hundred cubic feet, in which the apparatus is placed. The apparatus (see No. 1, *Plate* XXX., *fig.* 1) consists of an upright cast-iron cylindric boiler, about two feet in diameter; *b*, steam-condenser; G, G, G, &c., cast-iron pipes; *d*, the door for fuel; *c*, the ash-pit in a square base, on which the cylinder stands. No. 2, a vertical section; *h*, is the grate for coal; *i*, the boiler to be filled with water; *g*, smoke-funnel; the darts show the direction of the draft and smoke; *k*, the ash-pit.

*Fig.* 2, a horizontal section; *h*, the grate; *i*, the cavity filled with water, surrounding the grate and fire-place, smoke-flue, door-way, &c.; *g*, the smoke-funnel; G, G, G, &c., cast-iron pipes; *k*, cold-air conductor; *l*, *l*, walls of the air-chamber.

*Operation.* — The boiler and pipes are filled with water, also the steam-condenser about two thirds, leaving six inches of the upper part of the condenser for steam; when the water is at a boiling heat, it flows from the boiler and falls into the condenser, and descends through the pipes to the bottom of the boiler, and renews the heat from the fire and passes on as before, through the condenser, &c.; the revolution of the water will be in proportion to the degree of heat to which it is raised. The fresh air is admitted through the conductor, from the outside of the building, to the hot-air chamber, and is heated as it comes in contact with the boiler, tubes, &c., and, passing through tin or sheet-iron funnels, is admitted into the apartments through a register in the floor.

*Blaney's Furnace.* — This portable furnace is much in use, and gives general satisfaction for dry heat; it is used in dwelling-houses and public buildings with success.

*Plate* XXXIII., *fig*, 1, elevation; *fig*. 2, vertical section; the external air passes from the air-drain A, to the air-box B, through the tube C, into the cold-air chamber D, whence it rushes into the hot-air chamber E, through the apertures F, F, acting with rapidity upon the heated cylinder H, and the inner surface of the rarefying tubes I, I, and ascends, through the register M, into the apartment to be warmed.

A, air-drain; B, air-box; C, tubes to connect the air-box with the cold-air chamber; D, cold-air chamber; E, hot-air chamber; F, apertures; G, reflecting-case; H, fuel-cylinder; I, I, rarefying tubes; K, ash-pit; L, smoke-pipe; M, register; N, branch from the hot-air chamber; O, O, dampers. *Fig*. 3, plan of the base, C, C, &c., to connect the air-box with the cold-air chamber. *Fig*. 4, register.

*Plate* XXXI. shows the method of constructing kitchen fire-places, for heating boilers, stew-pans, and other culinary apparatus. *Fig*. 1, a vertical section, as represented on the plan, *fig*. 2, by the dotted line *a a*; *fig*. 2, plan for a double boiler, one set over the grate, the other over the space B; C, the construction of the flue, which is to be regulated by a slide *d*, *d*, *d*, the slope of brick-work rising above the sides of the grate. In this construction, one boiler is fixed immediately over the grate, and the other is placed over the space shown at *b*; the space *b* is made sufficiently capacious to admit a large proportion of the heated current of air, the direction of which is shown by darts, the flue being so constructed as to completely envelope the external surface of the two boilers. If the flues were made all the way along their course of equal capacity with the space contained around the grate, it is very clear, that, when the air became rarefied by the combustion of fuel, it would move in every part with an equal velocity, and the greatest portion of the heat would escape, without being imparted to the vessel and its contents intended to be heated. In order to prevent this, the area of the flue is contracted at *c*, by which means the heated air is detained much longer under the bottom of the boiler, and, impinging upon the surface of the vessel, tends to heat in the most advantageous manner, it being a well known fact that heat is best communicated by ascent; therefore, it will, at all times, be advantageous to detain the heated current as long as possible while it is covered by the under surface of the boiler. These reasons, if duly attended to, will, in every case, suggest to the practical bricklayer the most advantageous situation to construct the cheak or diminished area for the passage of the heated currrent. In cases where very great economy is requisite, as in steam-engine boilers, &c., the advantage of the ascending property of heat

# BLANEY'S WATER FURNACE

## FOR WARMING DWELLING HOUSES BY HEATED WATER

Fig 1.

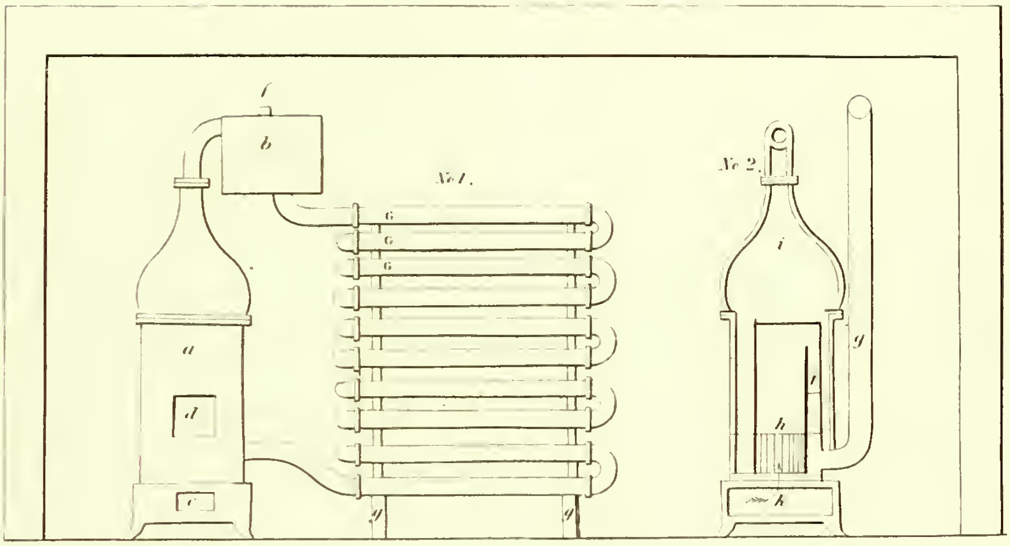
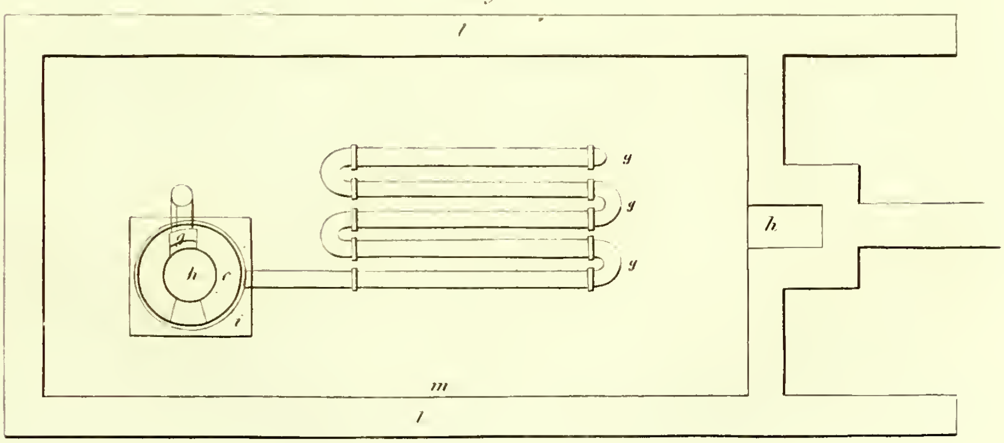



Fig 2.

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# BOILER FIREPLACES.

Fig 1.

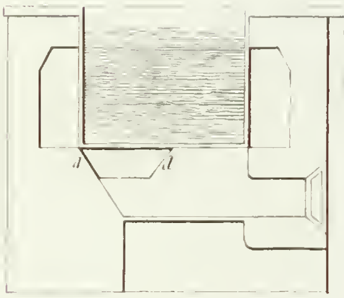



Fig 2.

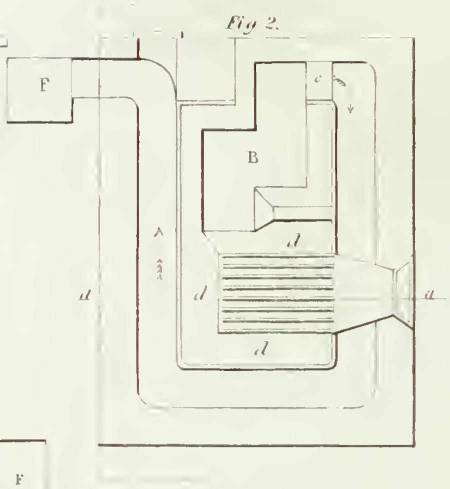



Fig 3.

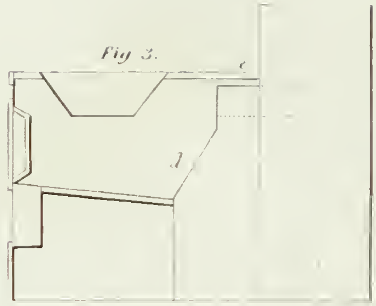



Fig 4.

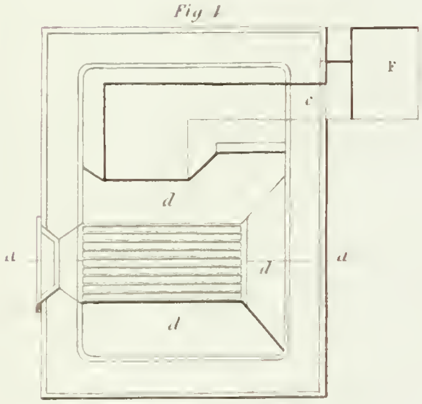



Fig 5.

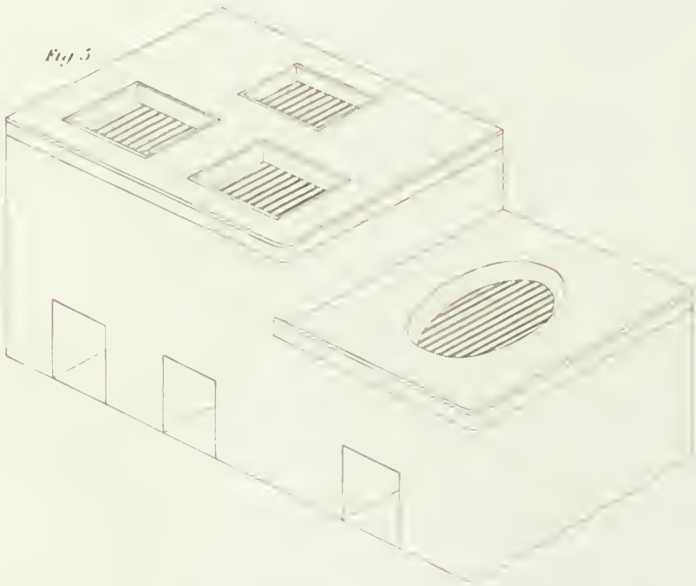
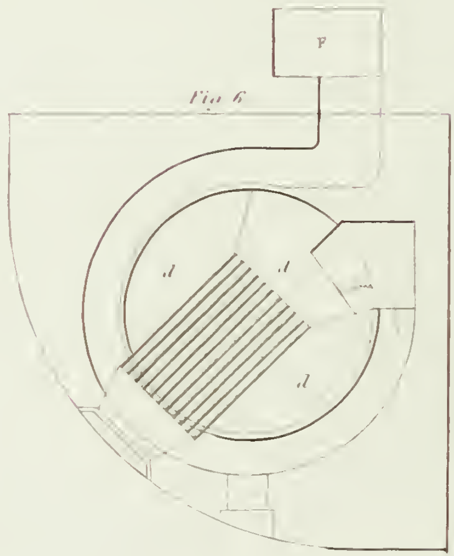


Fig 6.

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is so well understood by engineers, that they make the sides of their boilers project so as to form the upper surface of the enveloping flue, by which means they not only avail themselves of the lateral heat of the current, but also of that most important property before stated, namely, the ascending.

The sides around the grate, shown at *d, d, d, d, d,* should rise in a sloping direction, so as to accommodate the space to the rarefied air, after it has been heated by the combustion of fuel; and as these sides will have to sustain the greatest action of the heat, they being many times covered with the ignited fuel, it is absolutely requisite that they should be formed of the best fire-bricks and set in Stoarbridge clay, or fire-loam, mixed with ground clinkers from smiths' forges, which, when heated, will form a semi-vitrified mass that will bind and unite the whole mass firmly together. In all cases where it can be admitted, the approach to the narrowed passage to the current should be made to slope gradually upwards, which will assist to contract the current, like a funnel, at the same time that such an effect is greatly assisted by changing the direction of the heated medium.

In the construction of fire-places, in which it is intended that the heated air should be made to strike or impinge against any vessel in order to raise the temperature of its contents, it will be of the greatest importance to have all the brickwork done in the most thorough manner possible, as nothing can be more injurious than cracks or openings, which, by being connected with the flues, admit cold air into the heated current, and thereby destroy, in a great measure, the effect intended. To the practical man, who is aiming at eminence in his profession, we cannot too much enforce these observations, as they have been practically proved to be of the greatest importance.

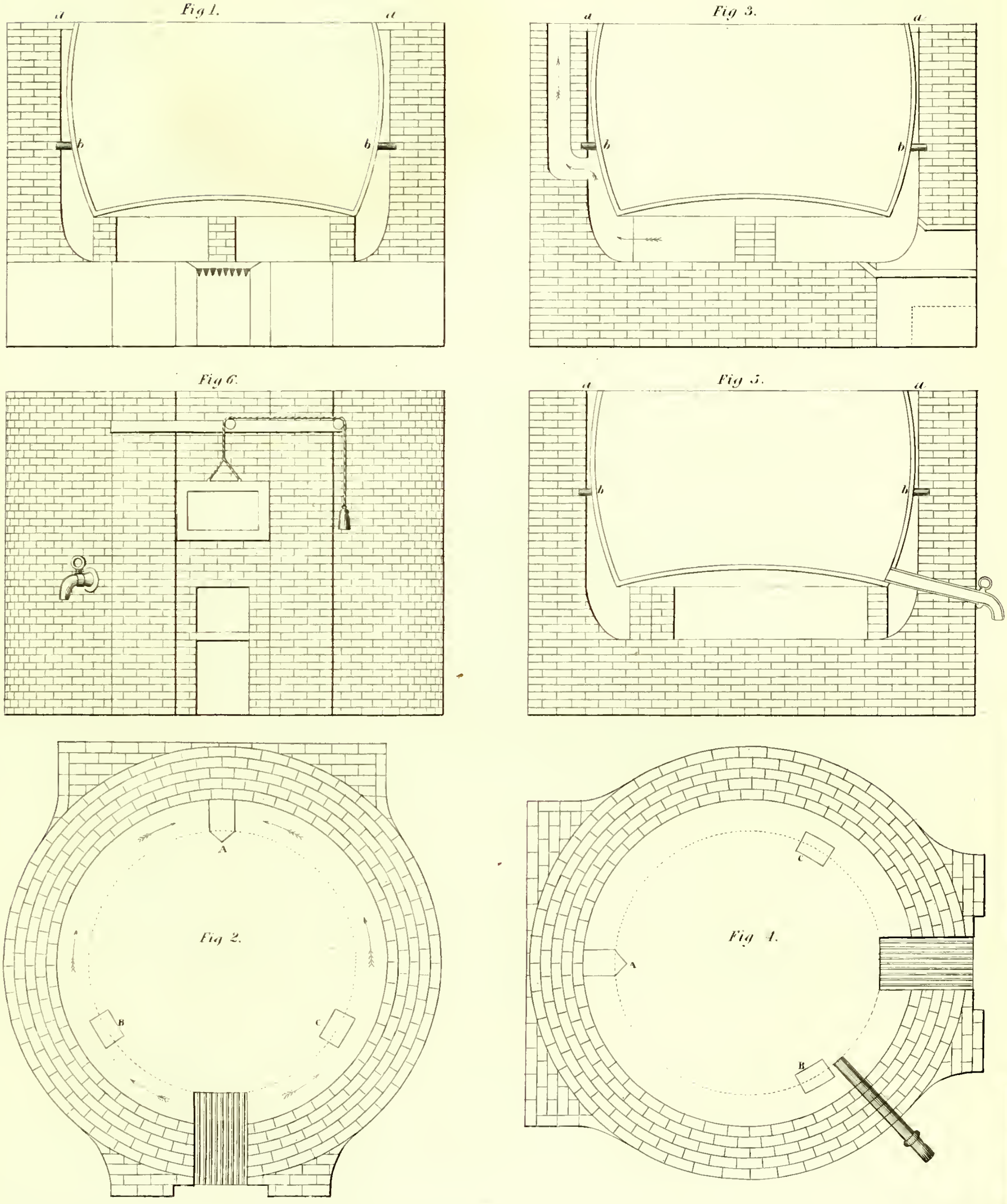
Before concluding these observations upon the construction of this class of fireplaces, we wish most strenuously to impress upon our practical readers the mistaken and false economy of making fire-grates too small, a practice that most completely defeats the principal object in view, namely, that of saving fuel. A very little reflection will clearly show, that where the space for fuel is too small, the want of room to spread the fuel will cause it to lay in such a compact and solid state, that the gaseous parts will be distilled and pass along the flue without being ignited, and by such means, instead of imparting heat by entering into combustion, a precisely contrary effect will be produced. And if, on the other hand, very small portions of fuel are frequently supplied, the opening of the door of the fire-place so repeatedly will permit so much cold air to enter as to essentially diminish the heating of the vessel and its contents, independently of the great loss of time that will be required to keep up a steady heat.

There is also another circumstance of great importance, which must be admitted into the consideration of this subject, namely, that where fire-places are made sufficiently large, fuel of a much coarser description can be used, and a very equable and economical heat may be produced; for, in such cases, the cinders and ashes from the common fire-grates, when mixed with a due proportion of small coals, will be not only sufficient for creating a proper heat, but will not require half the attendance that pure coals with a pinched fire-place will do.

We have been induced to make these observations, from a perfect conviction of their practical utility, having frequently observed the great loss that accrues, and the serious inconvenience that is sustained by many families who have employed persons to set the ordinary kitchen copper, which is too frequently executed upon such bad principles, that a great portion of the advantages and convenience of that very useful apparatus is lost. The length of the bars, in most cases, should be about three fourths of the diameter of the bottom of the boiler, and if they are loose bars they will be much better than a frame cut with all the bars entire. The space between each bar should be about half an inch. And it should be remembered that the flues of this kind of fire-places are as likely as others to be clogged with soot, and therefore it will be very requisite to have loose bricks, or stoppers, placed in proper situations, as shown at *c*, *fig.* 2, which will give great facility in cleansing such flues, and frequently prevent danger from fire in buildings where they may be erected. It may be necessary to state, that the same precautions and directions ought to be observed in *figs.* 3, 4, and 5, as in *figs.* 1 and 2. *Figs.* 3 and 4 represent a section and plan of a hot plate, *fig.* 3, which is most generally of cast-iron, resting about an inch on the brick-work all round, and a rim of wrought-iron should be fixed round the external brick-work, to protect it from being broken or otherwise damaged. The bridge of fire-brick ought to be built to within three-quarters of an inch of the plate, leaving that distance between the bridge and the under part of the plate for the smoke and heat to pass on the way to the chimney. The dotted line, in *fig.* 3, shows the position of the flue and the chimney. *Fig.* 5 is the plan of the copper boiler, with the bottom part contracted round the grate. The same rises at the opening in the back, passes round the bottom, and then enters the chimney.

*Fig.* 5 is the representation of a charcoal-stove, which is composed of solid brick-work, except it should so happen that a very large one should be wanted; then the wall may be built hollow and filled up with rubble. The grates are constructed of cast-iron, and placed four inches deep, with a vacuity under the floor for the ashes to drop, whence they may be drawn out through the cavity left in the front. Stoves of this description are used for stew-pans, chafing-dishes, &c. A rim of wrought-iron should be fixed round the brick-work at the top, about three and a half inches deep, or a covering of soap-stone an inch and a half thick, properly fitted; the grates are of different sizes, according to the magnitude of the building.

# COPPER BOILERS.

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*On the Method of fixing a Copper Boiler for Brewing.* — *Fig.* 1, *Plate* XXXII., is a section through the upper vertical line in the middle of the copper; *fig.* 2 is a horizontal section of the copper taken under the bottom, and may be considered as the plan of the brick-work immediately above the grate. This method offers the least obstruction for the flame to play on both sides where it meets on the opposite side of the prop at A, and thence rises in a sloping direction towards the back, which is shown by another section, *fig.* 3, the part at A being the partition, as shown on the plan, *fig.* 2. Above the partition, A, the whole of the smoke rushes into a chimney or tube ascending up the back of the brick-work, and is discharged into the atmosphere at the top. This chimney is shown in the section, *fig.* 3, which is taken at right angles to *fig.* 2, as exhibited by the plan, *fig.* 4, which is the plan of the second, *fig.* 3. *Fig.* 6 is an elevation of the front, showing the fire-place and the manner of suspending the door by means of pulleys, which is balanced by a weight depending from the remote pulley; the top of the brick casing round the copper is entirely closed round the circumference, as shown on the three sections at *a a*, *a a*, &c. There is a similar ring of brick-work which encompasses the circumference of the copper, and is also shown on these sections, at *b b*, *b b*, &c. This construction is that recommended by Mr. David Booth, a gentleman well known by his numerous publications, and his scientific acquirements on practical and useful subjects. We cannot conclude this department of instruction without again enforcing upon our scientific friends the absolute necessity of making the atmospheric air fall through the ignited fuel, and also of taking especial care that their work may be made so close and sound as to prevent a circulation of that which is very properly called the pabulum of life and flame; for one fact should never be lost sight of for an instant, namely, that whatever air is admitted, without being decomposed or used up by the fuel, must of course tend to impart its own temperature to the surrounding objects, and consequently rather retard than accelerate the object in view. We are well aware, that, however well fire-places of this kind may be constructed, much evil is frequently produced by having to join the flue, or carry it into one already formed. In such case it will generally be well to continue the flue belonging to the boiler fire-place to as great an extent as possible, before it enters the flue already formed, which will assist, in some degree, to obviate the difficulty. A portion of the flue that leads from the one not in use should be stopped, to prevent the entrance of air through it at such part.

*Bryent and Herman's Furnace.* — In building the brick-work for the furnace with an oven, the outside wall should be four feet six inches wide, by four feet deep from front to rear, as seen in *Plate* XXXIV., *fig.* 3.

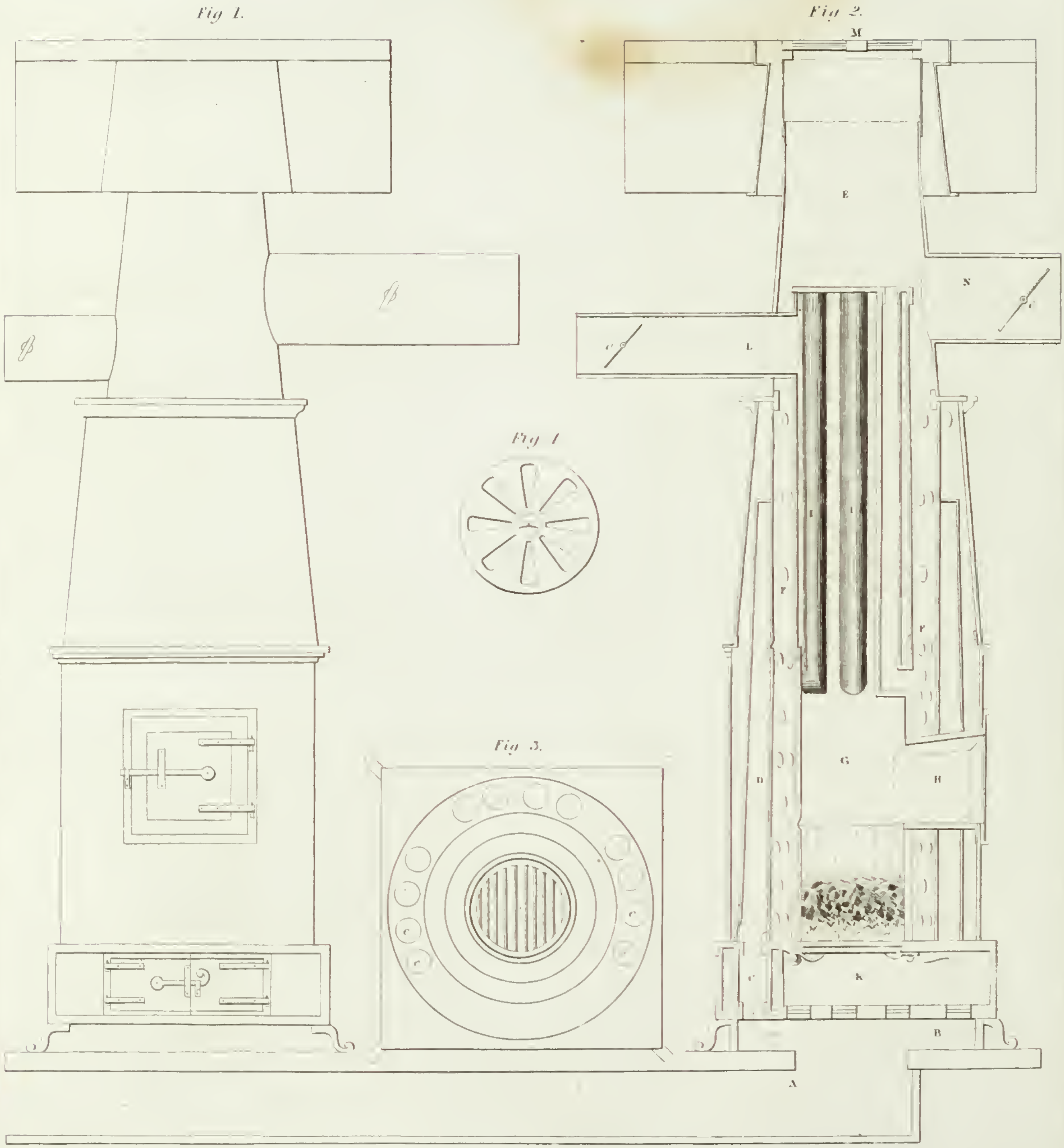
*Hot-air Furnace with Oven.* — Lay your foundation four feet six inches wide by four feet deep, and you will require as much as seven feet four inches in height. In laying out the foundation, you will build an eight-inch wall to place the plate on that supports the pot marked C; this wall makes your ash-pit; carry this wall up as high as the top of the door marked *i*; you will have two other walls, C and K, four inches thick, being four inches apart; carry these walls nearly as high as the plate, then head over the open spaces, so that the whole work shall be flush with the top of the plate. You will set bricks on end for the inner course, far enough apart to allow the lengths of bricks to span from centre to centre in laying flatways; this will leave holes about five and a half inches wide and seven and a half inches high; you will then proceed with this wall solid, four inches thick, as below, up to the top of the oven, when the hot-air pipe B, that goes *under* the covering can be put in; also the smoke-pipe C; you will then fill round the pipes even with the top of the pipes and cover over with bottom-stone, or iron bars and bricks. Now your inner wall is completed, your outside wall will continue as begun till you get about seven or eight inches above the inner covering, when that may be covered as the other, leaving a space open on one side for the cold air to enter, recollecting to set the bottom of the water-door even with the plate, and of course leaving a hole through both walls the size of the water-door. Care should always be taken that the brick and mortar do not touch the mouth or feeding door on the sides or top; if it does, the expansion of the iron, when heated, will crack the brick. The smoke-pipe should always be kept two and a half to three inches below the *lower* covering stone, to allow of its being taken out to repair if necessary without removing the covering stones. In setting the furnace with a drum, *fig.* 4, the work is nearly the same, with the exception that the outside of the brick-work will be five feet wide by four feet six inches deep, receding eight inches in front, having the recess about two feet wide. Seven feet high will answer for the No. 2 furnace, with drum. The plans given here are for the No. 2 furnace, which is the smallest but one. There are three sizes larger, Nos. 2½, 3, and 4. The size of the brick-work should increase six inches to the size No. 2½, five and a half feet by five feet; No 3, six feet by five and a half feet; No. 4, six and a half feet by six feet; or a little less than the above will answer. It will take about fourteen hundred brick for the No. 2 furnace, with an oven, and about sixteen hundred with a drum.

*Fig.* 1 represents the front elevation; *Fig.* 2, section of the base; *a* represents the cold-air box; *b*, hot-air pipes; *c*, outside of the elbow-tube; *d*, oven; *e*, smoke-pipe; *f*, feeding door for furnace; *g*, pot that contains the coal; *h*, pendulum grate; *i*, ash door or double door; *j*, inside wall; *k*, sifter grates for ashes; *l*, the outer wall; *m*, *figs.* 2 and 3, hot-air chamber; *n*, water-door; *o*, hole in the pendulum grate; *p*, *fig.* 4, drum; *q*, collar or drum to receive the smoke-pipe; *s*, cold-air passage.

Pl 33.

# BLANEY'S FURNACE,

*FOR HEATING DWELLING HOUSES*

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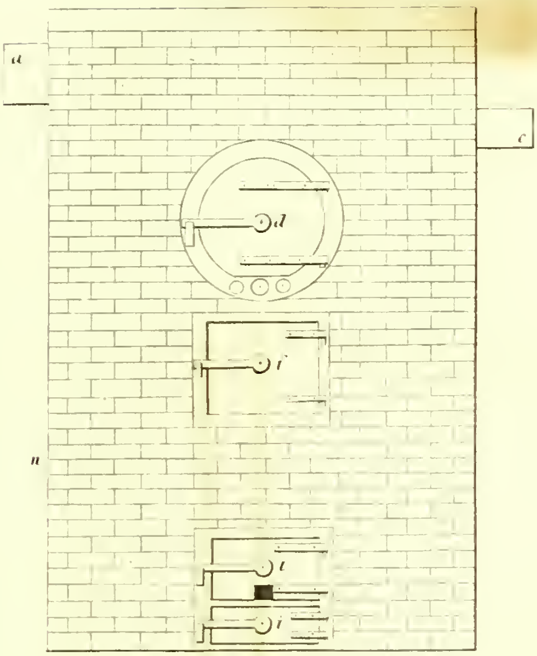
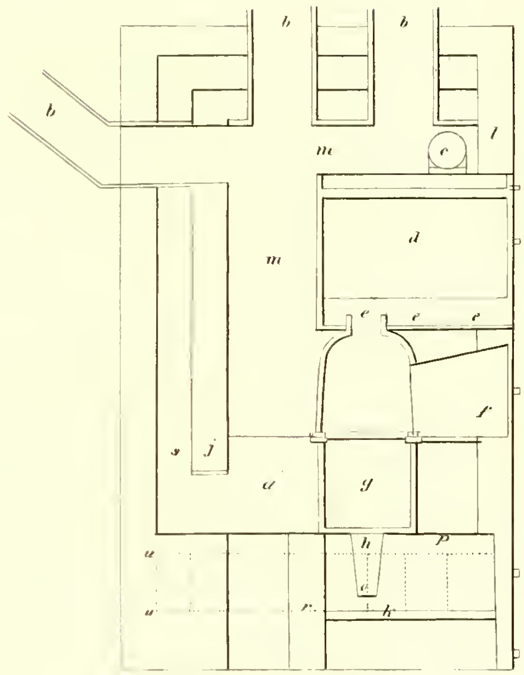
# BRYENT AND HERMANS FURNACE.

Fig 1.



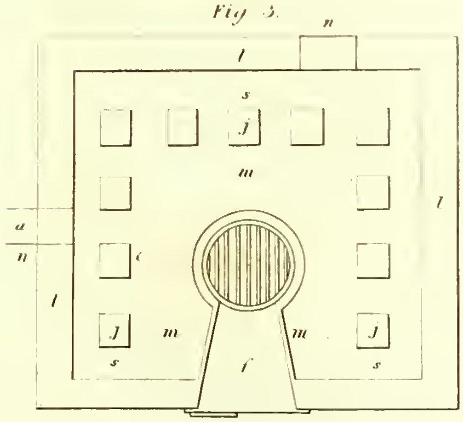

Front Elevation.

Fig 2.




Vertical Section.

Fig 3.




Plan

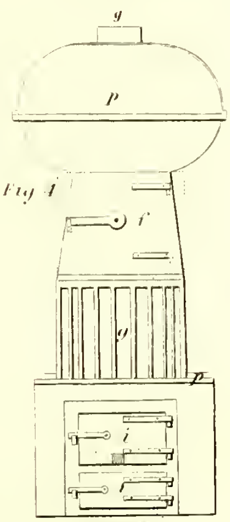



Fig 4.

Elevation


Scale of Feet.

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Pl 35.

# STIMSONS PATENT COOKING RANGE.

Fig 1.


Fig 3.


Fig 4

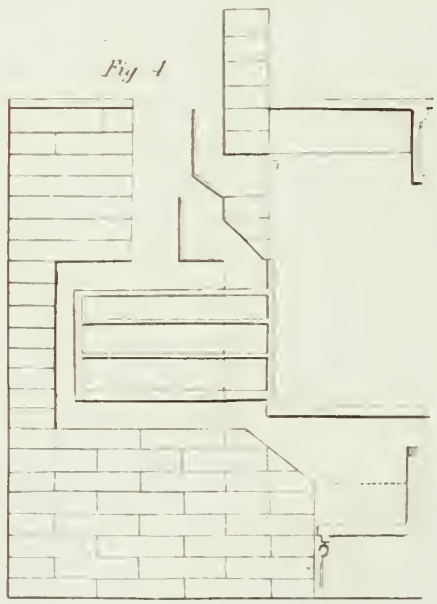
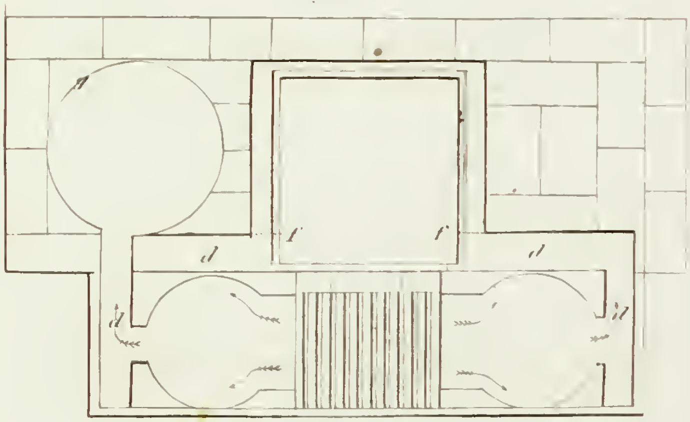


Fig 2




Scale

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*Stimpson's Patent Radiating and Hot-air Ranges.* — These ranges can be set either with or without the bath-boiler. They can also be set with hot-air fixtures, to heat an additional room with the same fire. They are manufactured of various sizes, to accommodate families, victualling establishments, boarding-houses, and taverns. They were originally invented more than fifteen years since. Many thousands have been sold, and have been in use from ten to fifteen years. They have been lately very much improved and newly patented, and are believed to be, so far as *economy of fuel, convenience of arrangement, durability, and facility for being repaired,* are good qualities, the best ranges now in use.

*Plate* XXXV. *Fig.* 1 is a front elevation of the range with bath-boiler ; *fig.* 2, a horizontal section just below the boiler plates, showing the course of the flues ; *fig.* 3 is a vertical section of the boiler and flues connected with it ; *fig.* 4 is a vertical section through the middle of the oven and of the fire-place, showing the course of the oven-flue.

In setting the range, first place the two sides, *a, a,* with the mantel, *b,* and the grate, *c,* supporting the ends of the side grates with short pieces of wood, till the brick is built up. Have these level and true, and be careful to leave space enough between them to allow for the expansion of the plate which goes over the fire. Now build up the brick-work level with the top of these sides, leaving the flues, as indicated by *d d d d.* The brick back, which is usually set with them, forms the back of the fire-place, and is bevelled at the top to fit the iron-work. Two fire-bricks (headers) should be placed under each of the side boiler holes, and the rest of the space under the boiler holes filled with common brick, taking care to leave a space of one inch underneath when the boilers are in. Now place the oven frame, *e,* and the oven partition, *f f ;* also the boiler casing, *g ;* the bottom of this casing should be level with the top of the sides, *a, a.* Build up around the oven with face brick. The space for the flues at the side is shown by ledges on the cast-iron partition, *f f ;* the space back of the oven should be an inch and a quarter. Fill in around the boiler casing all solid, leaving a flue at the top, which should enter the main flue.

## SECTION IX. — On the Construction of Ovens, Boilers, Fire-places, and of the Setting of Copper.

The section of the roof of the oven, on the old principle, for the use of bakers is usually of an oval figure, being arched over at the top in the figure of an ellipsoid ; the sides and bottom are of brick, tiles, and lime, with a door in front ;

and at the upper part is an inclosed closet, with an iron grating for the tins to stand on, called the proving-oven. To heat such ovens, fagots are introduced and burnt to ashes, which are then removed, and the bottom cleaned out. This operation requires some time, during which much of the heat escapes. A still further length of time is required for putting in the bread, and unless much more fuel is expended than is really necessary in heating an oven upon this principle, it becomes chilled before the loaves are all set in, and they are, therefore, by this means, very much injured.

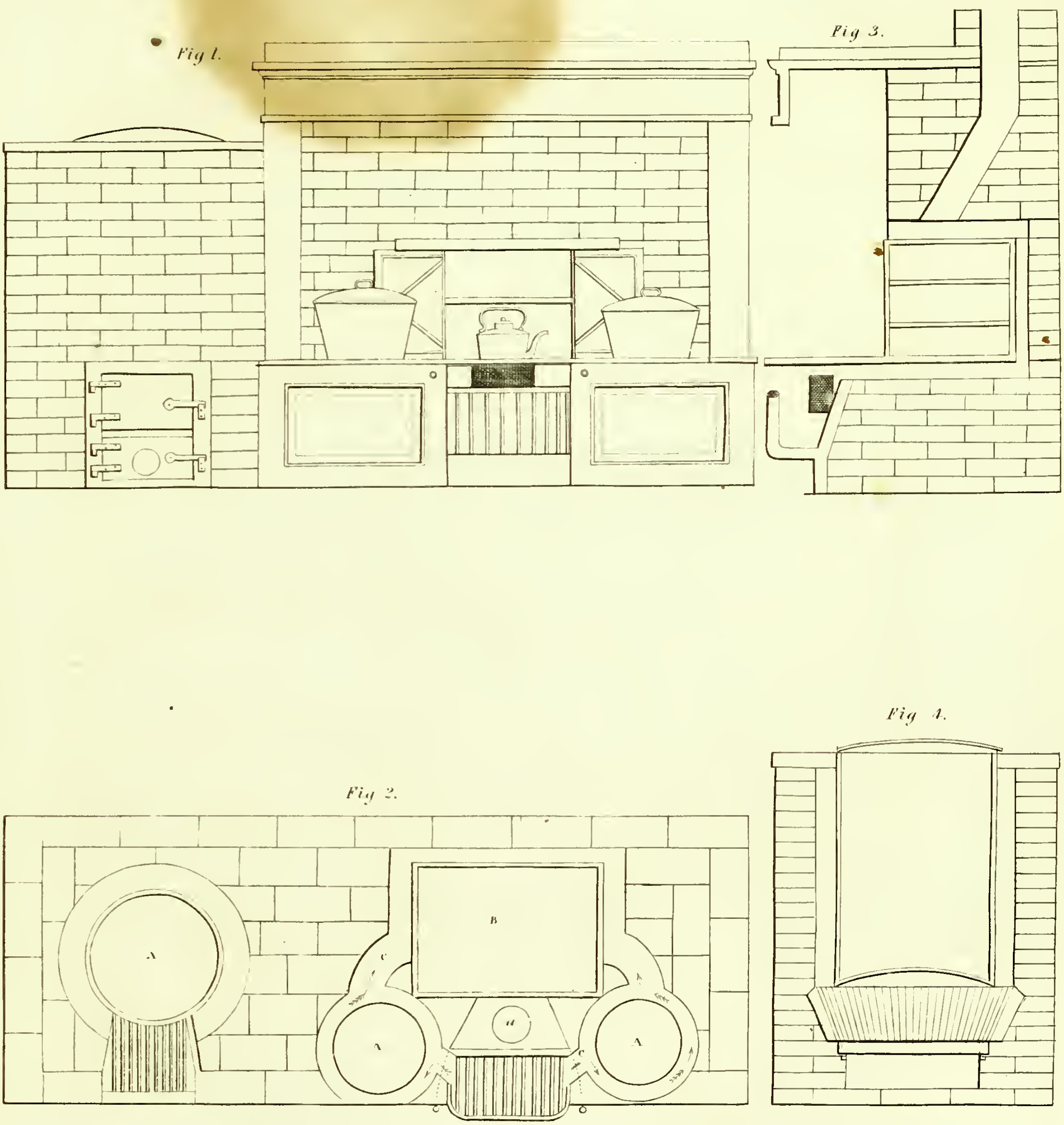
To remedy this inconvenience, many ovens have latterly been built upon a pavement, supported upon solid brick-work, with a door of iron, furnished with a damper to carry off the steam as it rises, and heated with fossil coal. On one side is a fire-place or furnace, with grating, ash-hole, and iron door, similar to that for supporting a copper, with a partition to separate it from the oven, and open at one end. Over this is a middling-sized copper or boiler, with a cock at the bottom, and on one side of it is placed the proving-oven, the whole being faced with brick and plaster.

When this oven is required to be heated, the boiler is filled with water, and, the fire being kindled, the flame spreads around, in a circular direction, all over its concavity, and renders it as hot as if heated with wood, without causing dirt or ill smell, while the smoke escapes through an aperture, which may pass into the kitchen chimney. When the coal is burnt to a cinder, there is no necessity for removing it, as it prevents the oven from cooling while the bread is setting in, and keeps up a regular heat till the door is closed. The advantages of an oven built upon this principle are too obvious to require comment.

*Plate* XXXVII., in detail, is an improved plan of an oven on the new construction. It has been constructed by Mr. Elms, the architect, under whose direction it has been placed in various public buildings in different parts of Europe. *Fig.* 1 is the plan of the oven; the fire is put into the furnace A, and is supported upon wrought-iron bars, which are fixed an inch and a half below the level of the oven, to prevent the cinders from entering it; the outside of the furnace is shut with two cast-iron doors (1, 2, in plan); the ashes fall into the ash-pit beneath, B (*fig.* 2), the door of which is marked 3 in the elevation (*fig.* 3). While the coals are burning, the mouth of the oven is inclosed only by the curve cast-iron door, or blower, B, shown in the section of the oven (*fig.* 4) and elevation (*fig.* 10), and which is so shaped in order to make a proper passage for the smoke to the flue, C; this door, or blower, is not hung, but is put up and taken away by hand, as may be required. When the oven is sufficiently hot, the tender or baker stationed at the mouth, with an iron bar (*fig.* 5), slides the cast-iron stopper D (*figs.* 1 and 6) to the angle F, where it stops, as

Pl 36.

# STIMSONS PATENT COOKING RANGE.

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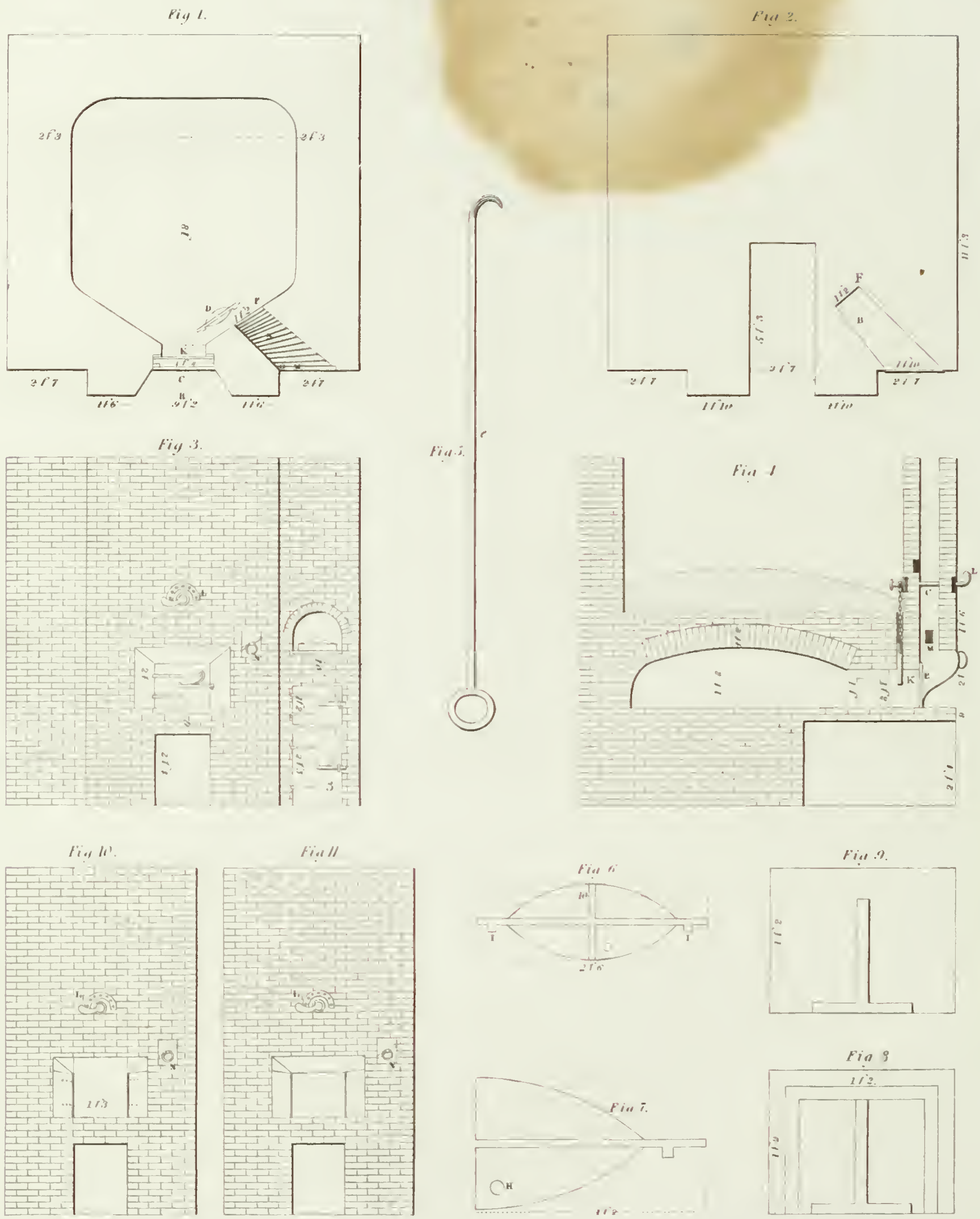
Pl. 37.

# COAL OVEN FOR BAKERS,

ON A NEW PRINCIPLE

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shown by the dotted line; then, going to the mouth of the furnace, he hooks the crooked part of the same iron bar (*fig.* 8) into the circular hole of the stopper H (*fig.* 7), and pulls the fillet (*fig.* 8) into the frame of the furnace, upon which it fits. This stopper is made to slide, but not in a groove, as the cinders might sometimes prevent its being shut. *Fig.* 8 represents an iron frame, to be fixed round the mouth of the inside of the furnace; the opening of the mouth should be one foot two inches wide, and one foot high, and should be made to receive the fillets of the stopper.

The door, K (*fig.* 4), is fastened to an iron chain, and is raised or let down at pleasure by turning the lever L (*figs.* 4 and 10). In order to prevent the heat from escaping while the bread is putting in, the mouth of the oven must be made as small as possible. To the handle of the lever is hung an iron pin, with a chain, and over it is a semicircular iron plate, fastened to the wall, with five holes to receive the pin, by which the height of the door, K, may be regulated at pleasure.

When bread is baking, the curved door B, not being then wanted, is taken away; and the two doors of the oven, with the two doors of the furnace, are shut up. At the top of the furnace, M (*fig.* 4), is a small flue, about three inches square, communicating with the flue of the oven. The use of this small flue is to leave a passage for the sulphur that may remain in the ashes, and might injure the bread while baking. The communication of this small flue of the oven is opened or shut by means of an iron slider, N (*fig.* 10). Over the furnace is a niche (*fig.* 3), with a boiler of hot water.

It has been observed, that, in ovens with this construction of the fire-place, it is always proper to set the bars eight or ten inches in from the door; by this means a supply of coals will be kept warming before they are pushed forward into the fire. The importance of this preparation is known to those who have attended to the effect of every fresh supply of coals to the boilers of steam-engines, as it instantly stops the boiling, unless this precaution is attended to. It also prevents, in a great measure, the cold air getting in between the door and frame of the fire-place, which frequently happens, from the difficulty of fitting iron doors to iron frames.

Ovens, on the improved construction, will hold, according to their size, as follows: — eight feet wide and seven deep, ten bushels of bread; nine feet wide and seven and one half feet deep, ten bushels; ten feet wide and eight and a half feet deep, twelve bushels.

*Plate* XXXVIII. This plate represents a baker's oven, heated by coal; this oven has many advantages over any other; its construction is simple, as will be seen by reference to the plan; it economizes labor, as, when the oven is properly heated, and with a proper quantity of coal and a well regulated fire, a tender stationed at the mouth may, when the bottom of the oven is covered with bread, begin to take out where he began to set in, and thus continue his labors as long as he pleases, without being obliged, as in other ovens, to stop and renew the heat and clean the bottom; here the heat and labor is continually kept up, therefore one half of the time may be saved. This oven is built of brick, as shown by *figs.* 1, 2, 3, and 4. *Fig.* 1, front elevation; *a*, the entrance to the cavity under the bottom; *b*, the ash-pit; *c*, the door inclosing the grate; *d*, the oven-door; the doors and frames made of cast-iron; in the ash-pit door, a slide to regulate the draft of air. *Fig.* 2 is a horizontal section at the bottom of the oven; the darts show the direction of the heat and smoke, inclosed by a sheet-iron funnel twelve inches perpendicular, and four inches on the horizontal line, leading from the coal-grate to the chimney-flue, around the outside of the oven-hearth; near the entrance to the chimney-flue is a slide to retain the heat in the funnel at pleasure. *Fig.* 3, a horizontal section under the hearth; *a*, the entrance under the hearth; *b*, the cavity; *c*, a centre pier to support the bottom of the oven, scale four feet to an inch. *Fig.* 4, a vertical section; *a a*, smoke-flue through which the heat passes from the grate to the chimney-flue, through sheet-iron funnel nearly surrounding the interior at the bottom, diffusing the heat into the oven; a space of time usual for the ordinary heating at first will be all the hindrance for the day, and the tender then takes his station at the oven-door; *b b*, cavity under the bottom; *c*, the arch of the oven; *d d*, space above the arch, generally filled in with a portion of sand to retain the heat.

# IMPROVED BAKERS COAL OVEN.

Fig 1

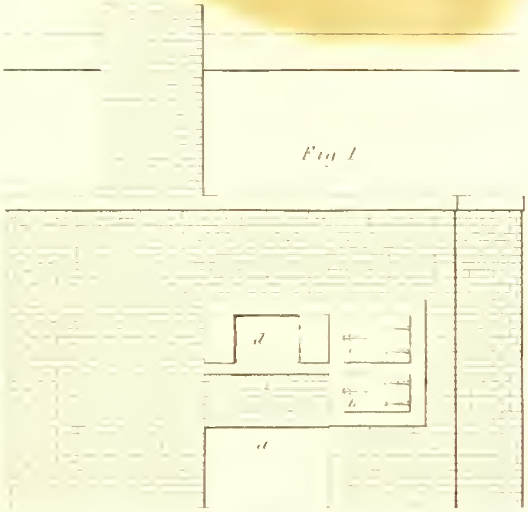



Fig 1.

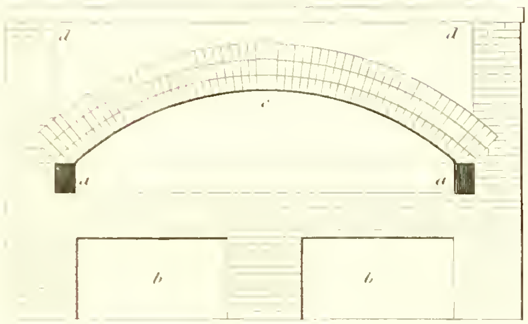



Fig 2.

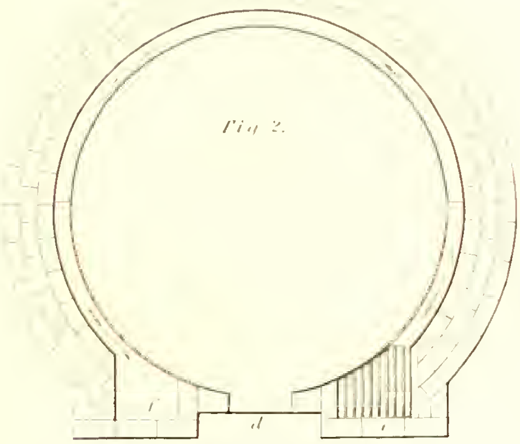
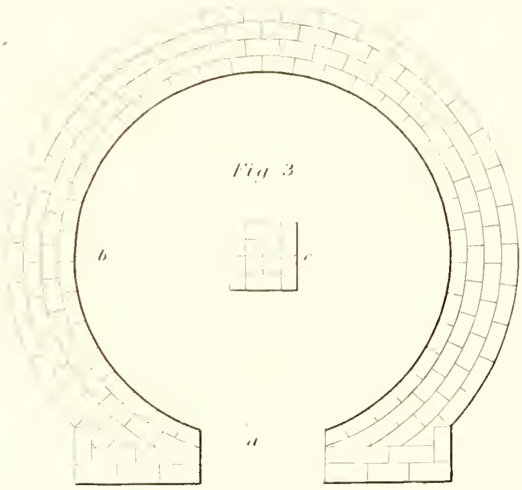



Fig 3

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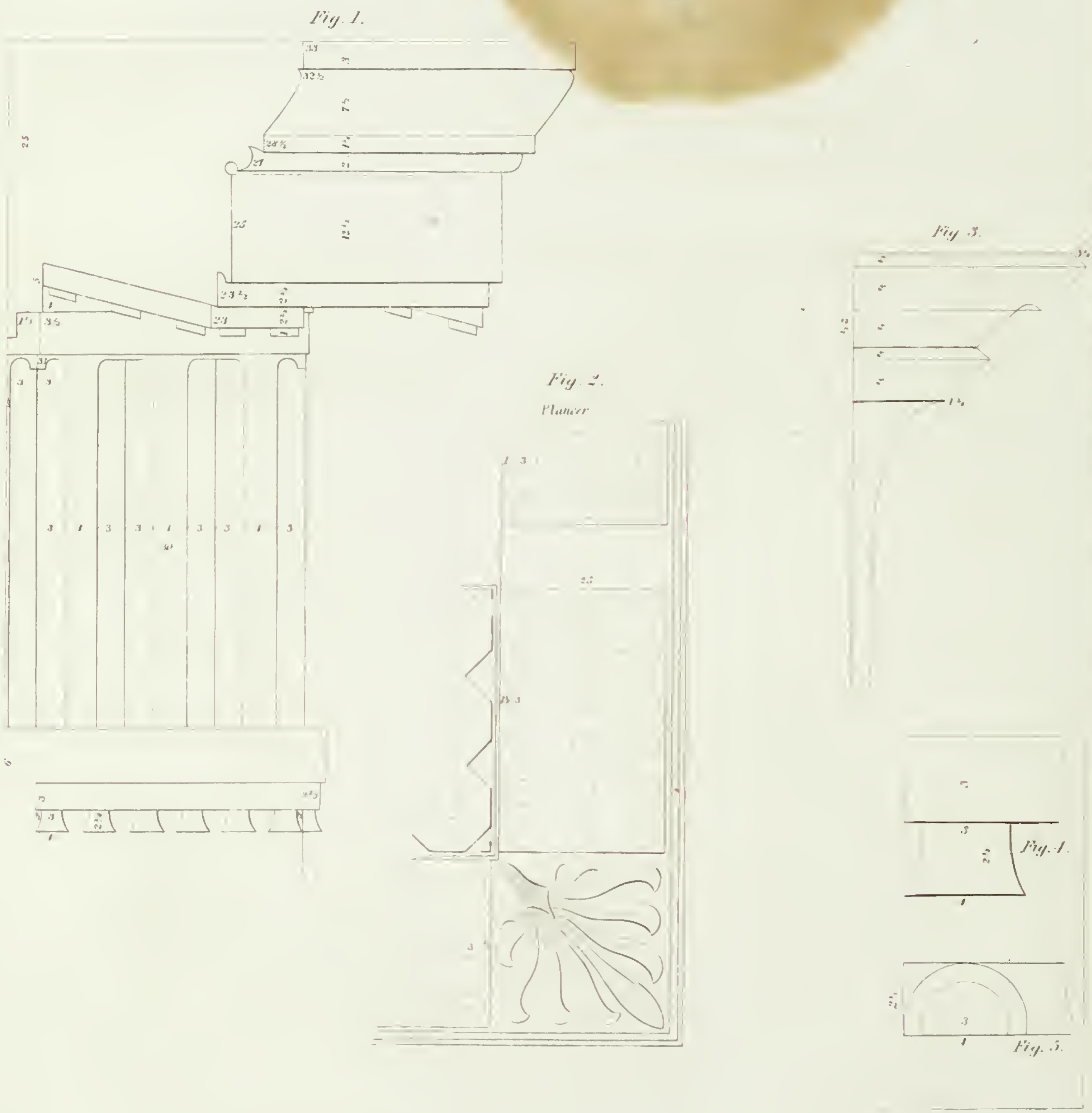
Pl 39.

# DORIC DETAILS.

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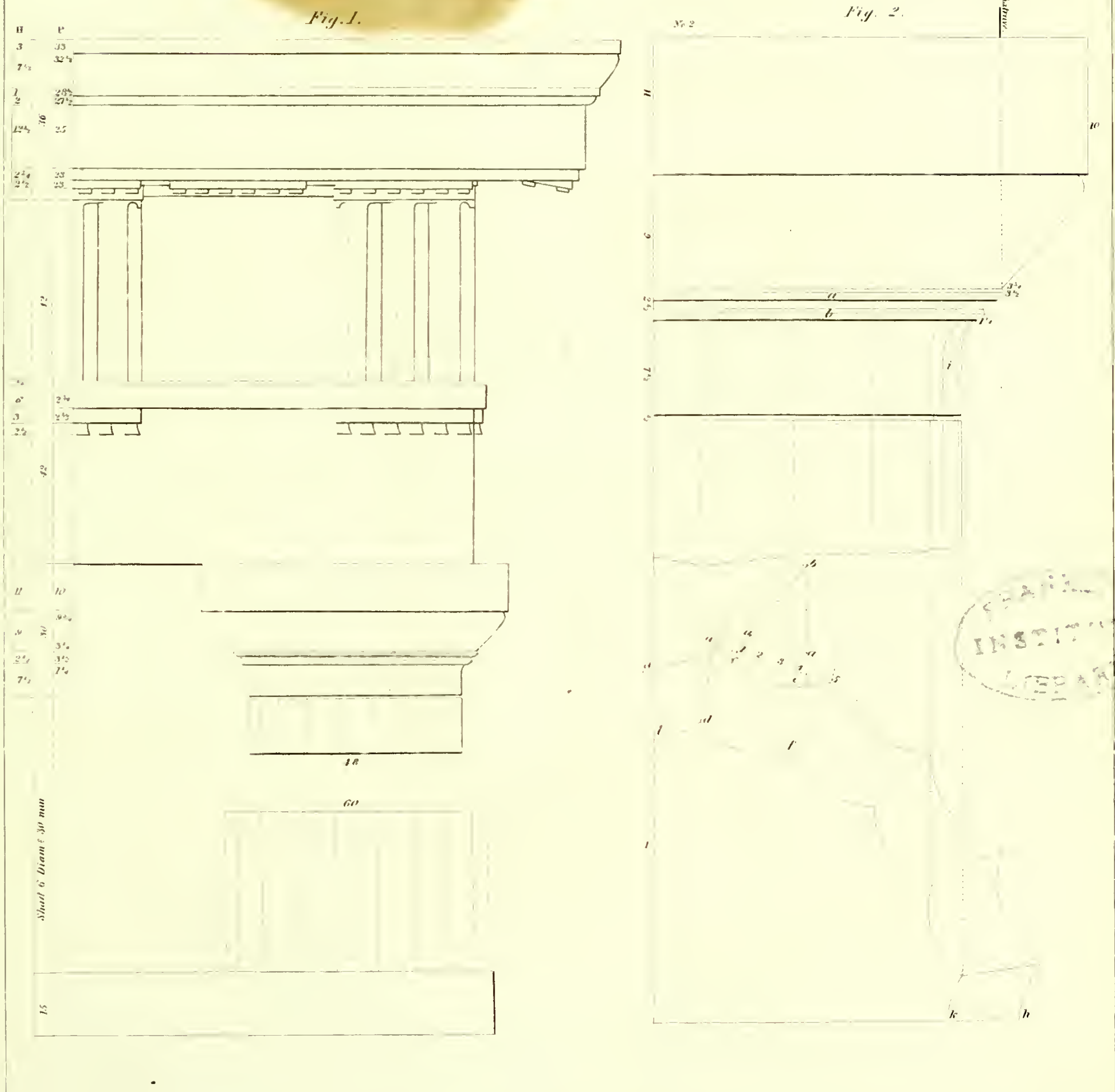
# DORIC ORDER.



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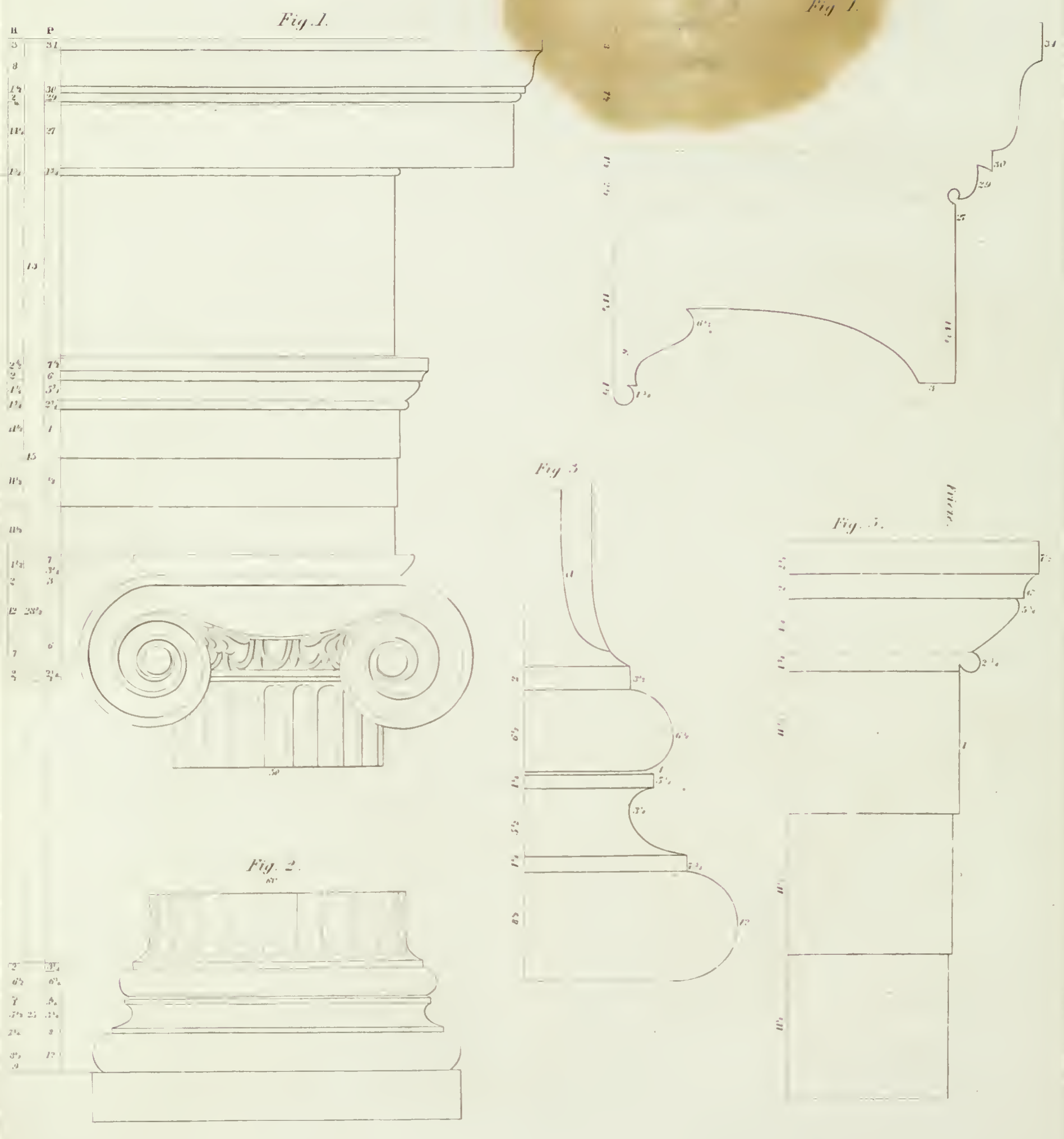
Pl. 41.

# IONIC ORDER.

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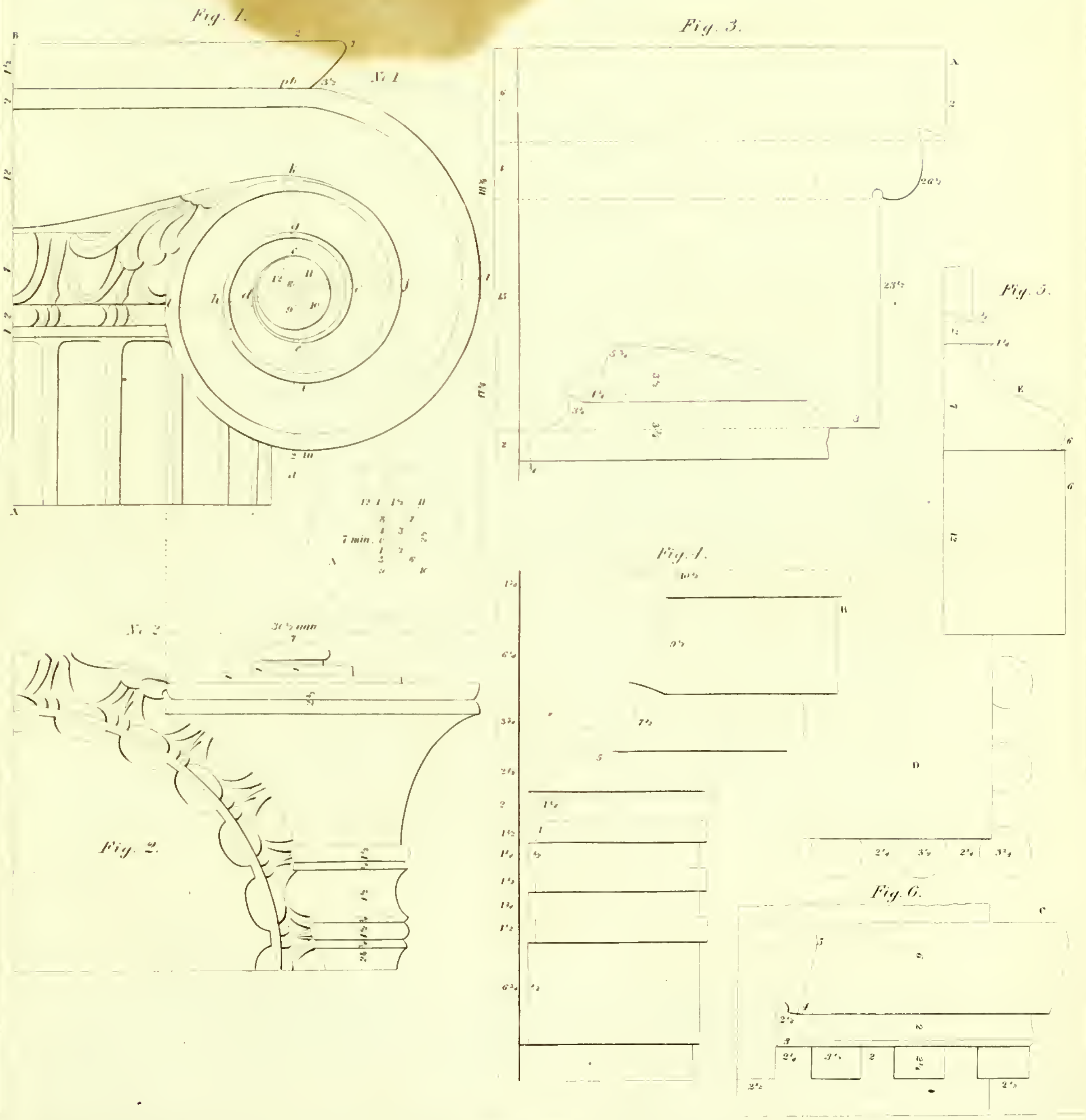
# IONIC DETAILS.

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# CHAPTER VI.

## ORDERS OF ARCHITECTURE.

### SECTION I. — Grecian Doric.

I have here made use of the Grecian example given by Vitruvius, from the Temple of Minerva, on the Acropolis at Athens, built under the administration of Pericles, the representation of which is found in *Plate* XXXIX. *Fig.* 1, a section of the entablature, showing the manner of finish and the form of the mouldings inside the portico. *Plate* XL., *fig.* 2, a section of the column at both ends, with twenty flutes and the manner of striking them; divide the circumference into twenty equal parts; trace lines to the centre; with the dividers draw a line, for the circumference of the top, intersected by the radius *a b;* extend the dividers from *c* to *d*, and, for the circumference of the lower diameter, to *g;* and from *e*, describe the curve for the flute *e f;* and in like manner for the upper diameter, as shown by *g e f*. *Plate* XXXIX., *fig.* 2 represents the planceir, with the mutules, having three rows of pins, six in each row, which are said to have arisen from the idea of the ends of rafters forming the roof. *Fig.* 4, the elevation of the triglyphs, containing two whole and two half channels. *Fig.* 5 shows a section of the guttæ, or drops, that are formed under the triglyph, or under the fillet of the architrave. *Plate* XL., *fig.* 2, the capital of column; *a*, *b*, the annulets formed on the lower part of the ovolo.

*Plate* XL. *Fig.* 1, the proportional figures from the scale of the column. Divide the lower end into two equal parts; each is called a *module;* divide the module into thirty parts, which are called minutes, as figured on the order; under the column H is the height of each member, and under the column P their projections from a line drawn perpendicular through the centre of this column; the entire height of the order in this example is divided into eight parts, making eight diameters and thirty-five minutes. *Fig.* 2, the scale of diameter. *Fig.* 3, the lower part of the same. *Fig.* 4, the whole height of the order, the letters on the same are references to the introduction.

### SECTION II. — Grecian Ionic.

*Plate* XLI. *Fig.* 1, the example from the Temple of Minerva Polias, leaving the ornamented mouldings for those who prefer to make use of them in more expensive structures. The proportional measures are given on the margin in height and projections. *Fig.* 2, the Ionic base. *Fig.* 3, elevation of the order. See figures on the margin. This style of base, the Attic, or the base on pilasters, *Plate* XLII., *fig.* 1, may be used as may be most appropriate for the structure into which they are introduced. The Ionic base may be most proper for common use.

*Plate* XLII. *Fig.* 4, a pilaster or anta to the Ionic column; *Fig.* 2, the original cap figured in the columns H, P, *Plate* XLI., *fig.* 1; *Fig.* 3, base. See figures for proportions.

### SECTION III. — Grecian Corinthian.

This order seems to have taken rise in the flourishing days of Corinth, a celebrated city of Greece. The proportions of the order resemble the graceful figure of a virgin, more delicate than the more mature age of the matron, which has given rise to the Ionic proportions. The composition of foliage is considered the leading character of the Corinthian capital, which is arranged in two annular rows of leaves, so that each leaf in the upper row grows up between those of the lower row, in such a manner that a leaf of the upper row will stand in the middle of each face of the capital, and from each leaf of the upper row three stalks spring with volutes, two of them meeting under the angle of the abacus, and two in the centre of the side, touching or interwoven with each other. A capital thus constructed is called Corinthian.

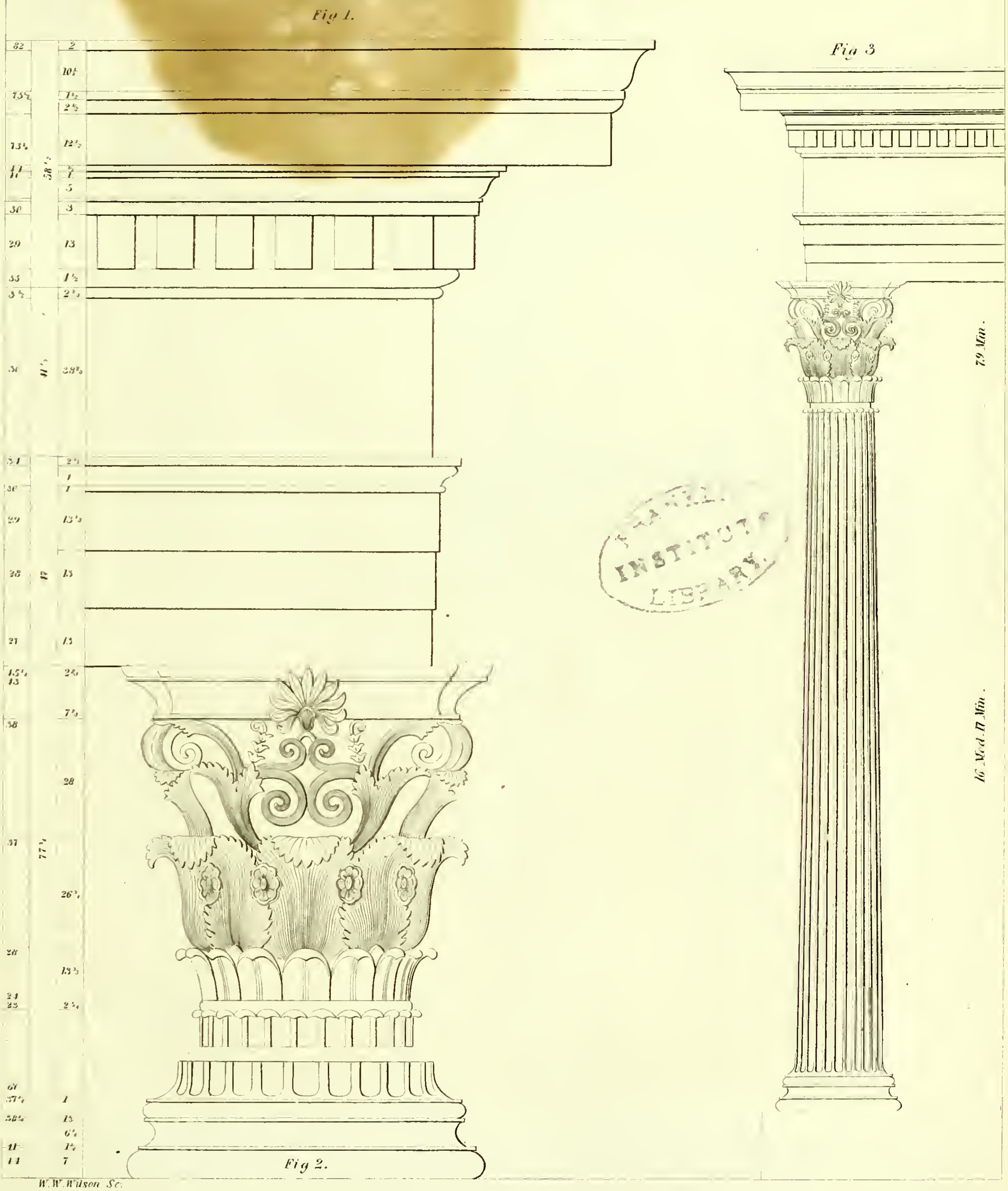
*Plate* XLIII. This example is from the Lantern of Demosthenes, otherwise called the Monument of Lysicrates. With some variation in the entablature and dentils, it may be considered a beautiful specimen of the Grecian art, and may be imitated with success when elegance is required in the composition. *Fig.* 1 represents the entablature and cap of the column. *Fig.* 2, the base, dimensions of height and projections figured under P, H, from a scale of sixty minutes for the diameter of the column at the base. *Fig.* 3, the full length column, entire height of the order.

*Plate* XLIV. *Fig.* 1, a design for antæ for the columns, *Plate* XLIII. The face of this anta, or pilaster, is equal to the diameter of the column at the neck, and equal in width at top and bottom; thus avoiding the difficulty of increasing the projection of the capital beyond that of the column to which it may be attached. *Fig.* 2, the capital of column, *Plate* XLIII., *fig.* 1. Inverted and horizontal section of the column and flutes at the neck. *Fig.* 3, the cornice, inverted.

The Romans, adopting the general features of this order, introduced into it some variations from the Greek specimens.

Pl 43.

# GRECIAN CORINTHIAN.

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# GRECIAN CORINTHIAN.

*Fig 1.*

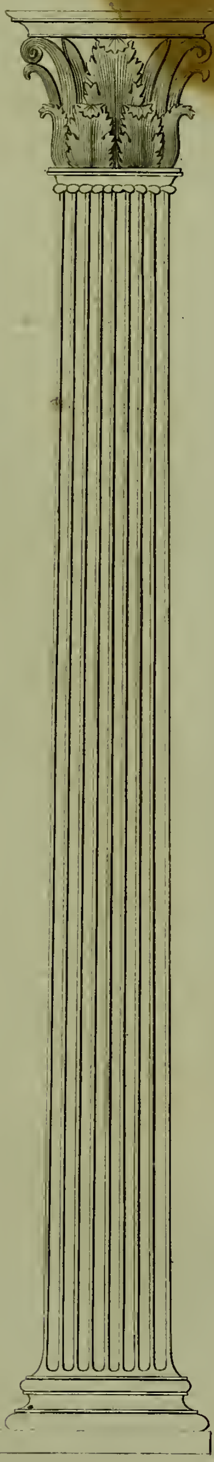
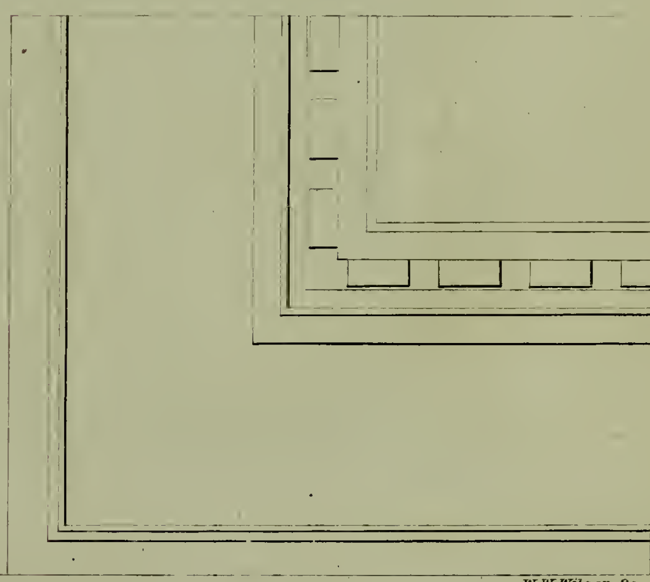


*Fig 2*



*Fig 3.*



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# GLOSSARY

OF

# ARCHITECTURAL TERMS.

*Abacus.* The upper member of the capital of a column whereon the architrave rests. Scammozzi uses this term for a concave moulding in the capital of the Tuscan pedestal, which, considering its etymology, is an error.

*Abutment.* The solid part of a pier from which an arch springs.

*Acanthus.* A plant called in English *Bear's Breech*, whose leaves are employed for decorating the Corinthian and Composite capitals. The leaves of the acanthus are used on the bell of the capital, and distinguish the two rich orders from the three others.

*Accompaniments.* Buildings, or ornaments, having a necessary connection or dependence, and which serve to make a design more or less complete; a characteristic peculiarity of ornaments.

*Accouplement.* Among carpenters, a tie or brace; sometimes the entire work when framed.

*Acroteria.* The small pedestals placed on the extremities and apex of a pediment.

*Admeasurement.* Adjustment of proportions; technically, an estimate of the quantity of materials and labor of any kind used in a building.

*Alcove.* The original and strict meaning of this word, which is derived from the Spanish *alcoba*, is that part of a bed-chamber in which the bed stands, and is separated from the other parts of the room by columns or pilasters.

*Amphiprostyle.* In ancient architecture, a temple with columns in the rear as well as in the front.

*Amphitheatre.* A double theatre, of an elliptical form on the ground plan, for the exhibition of the ancient gladiatorial fights and other shows.

*Ancones.* The consoles or ornaments cut on the keys of arches, sometimes serving to support busts or other figures.

*Annulet.* A small square moulding, which crowns or accompanies a larger. Also, that fillet which separates the flutings of a column. It is sometimes called a *List*, or *Listella*, which see.

*Antæ.* A name given to pilasters attached to a wall.

*Apophyge.* That part of a column between the upper fillet of the base and the cylindrical part of the shaft of the column, which is usually curved into it by a cavetto.

*Aræostyle.* That style of building in which the columns are distant four, and sometimes five, diameters from each other; but the former is the proportion to which the term is usually applied. This columnar arrangement is suited to the Tuscan order only.

*Arcade.* A series of arches, of apertures, or recesses, a continued covered vault, or arches supported on piers or columns instead of galleries. In Italian towns, the streets are lined with arcades like those of Covent Garden and the Royal Exchange.

*Arch.* An artful arrangement of bricks, stones, or other materials, in a curvilinear form, which, by their mutual pressure and support, perform the office of a lintel, and carry superincumbent weights,—the whole resting at its extremities upon piers or abutments.

*Arch-buttress*, or *Flying-buttress*, (in Gothic architecture,) an arch springing from a buttress or pier, and abutting against a wall.

*Archeion.* The most retired and secret place in Grecian temples, used as a treasury, wherein were deposited the richest treasures pertaining to the deity to whom the temple was dedicated.

*Architect.* One who designs and superintends the erection of buildings.

*Architrave.* The lower of the primary divisions of the entablature. It is placed immediately upon the abacus of the capital.

*Astragal.* From the Greek word for a bone in the foot, to which this moulding was supposed to bear a resemblance. A small moulding, whose profile is semicircular, and which bears also the name of *Talon*, or *Tondino*. The astragal is often cut into beads and berries, and used in ornamental entablatures to separate the faces of the architrave.

*Attic.* A term that expresses any thing invented or much used in Attica, or the city of Athens. A low story erected over an order of architecture, to finish the upper part of the building, being chiefly used to conceal the roof, and give greater dignity to the design.

*Attic Base.* See *Base.*

*Attic Order.* An order of low pilasters, generally placed over some other order of columns. It is improperly so called, for the arrangement can scarcely be called an order.

*Auriel*, or *Oriel*, (in Gothic architecture,) a window projecting outwards for private conference: whence its appellation.

*Balcony.* A projection from the surface of a wall, supported by consoles or pillars, and surrounded by a balustrade.

*Baluster.* A small pillar, or pilaster, serving to support a rail. Its form is of considerable variety, in different examples. Sometimes it is round, at other times square; it is adorned with mouldings and other decorations, according to the richness of the order it accompanies.

*Balustrade.* A connected range of a number of balusters on balconies, terraces around altars, &c. See *Baluster.*

*Band.* A term used to express what is generally called a *Face*, or *Facia.* It more properly means a flat, low, *square-profiled* member, without respect to its place. That from which the Corinthian or other modillions, or the dentils, project, is called the modillion band, or the dentil band, as the case may be.

*Bandelet.* A diminutive of the foregoing term, used to express any narrow flat moulding. The tænia on the Doric architrave is called its bandelet.

*Banker.* A stone bench on which masons cut and square their work.

*Banquet.* The foot-way of a bridge raised above the carriage-way.

*Barrel Drain.* A drain of the form of a hollow cylinder.

*Base.* The lower part of a column, moulded or plain, on which the shaft is placed.

*Basement.* The lower part or story of a building, on which an order is placed, with a base or plinth, die, and cornice.

*Basil.* A word used by carpenters, &c., to denote the angle to which any edge-tool is ground and fitted for cutting wood, &c.

*Basin*, *en Coquille*, that is, shaped like a shell.

*Basin* is likewise used for a dock.

*Basket.* A kind of vase in the form of a basket filled with flowers or fruits, serving to terminate some decoration.

*Bassilica.* A town or court-hall, a cathedral, a palace, where kings administer justice.

*Basso-relievo*, or *Bass-relief.* The representation of figures projecting from a back-ground, without being detached from it. Though this word, in general language, implies all kinds of relievos, from that of coins to more than one half of the thickness from the back-ground.

*Bath.* A receptacle of water appropriated for the purpose of bathing.

*Batten.* A scantling of stuff, from two to six inches broad, and from five eighths to two inches thick, used in the boarding of floors; also upon walls, in order to secure the lath on which the plaster is laid.

*Batter.* When a wall is built in a direction that is not perpendicular.

*Battlements.* Indentations on the top of a parapet, or wall, first used in ancient fortifications; and afterwards applied to churches and other buildings.

*Bay*, (in Gothic architecture,) an opening between piers, beams, or mullions.

*Bay Window.* See *Auriel.*

*Bead and Flush Work.* A piece of panel-work, with a bead run on each edge of the included panel.

*Bead and Butt Work.* A piece of framing in which the panels are flush, having beads stuck or run upon the two edges, with the grain of the wood in their direction.

*Bed-Mouldings.* Those mouldings in all the orders between the corona and frieze.

*Billet-Moulding*, (in Gothic architecture,) a cylindrical moulding, discontinued and renewed at regular intervals.

*Boltel*, (in Gothic architecture,) slender shafts, whether arranged round a pier, or attached to doors, windows, &c. The term is also used for any cylindrical moulding.

*Boss*, (in Gothic architecture,) a sculptured protuberance at the interjunction of the ribs in a vaulted roof.

*Bossage.* (A French term.) Any projection left rough on the face of a stone for the purpose of sculpture, which is usually the last thing finished.

*Boultin.* A name given to the moulding, called the egg or quarter-round.

*Broach*, (in Gothic architecture,) a spire, or polygonal pyramid, whether of stone or timber.

*Bracket*, (in Gothic architecture,) a projection to sustain a statue, or other ornament; and sometimes supporting the ribs of a roof.

*Bulk.* A piece of timber from 4 to 10 inches square, and is sometimes called ranging timber.

*Buttress*, (in Gothic architecture,) a projection on the exterior of a wall, to strengthen the piers and resist the pressure of the arches within.

*Cabling.* The filling up of the lower part of the fluting of a column with a solid cylindrical piece. Flutings thus treated are said to be cabled.

*Caisson.* A name given to the sunk panels of various geometrical forms, symmetrically disposed in flat or vaulted ceilings, or in soffits, generally.

*Canopy*, (in Gothic architecture,) the ornamented drip-stone of an arch. It is usually of the ogee form.

*Canted* (in Gothic architecture.) Any part of a building having its angles cut off, is said to be canted.

*Capital.* The head or uppermost part of a column or pilaster.

*Carpenter.* An artificer whose business is to cut, fashion, and join timbers together, and other wood for the purpose of building; the word is from the French *charpentier*, derived from *charpentie*, which signifies timber.

*Carpentry*, or that branch which is to claim our attention, is divided into three principal heads, viz., Constructive, Descriptive, and Mechanical; of these, Descriptive carpentry shows the lines or methods for forming every species of work in *plano*, by the rules of geometry; Constructive carpentry, the practice of reducing the wood into particular forms, and joining the forms so produced, so as to make a complete whole, according to the intention of the design; and Mechanical carpentry displays the relative strength of the timbers, and the strains to which they are subjected by their disposition.

*Cartouch.* The same as modillions, except that it is exclusively used to signify those blocks or modillions at the eaves of a house. See *Modillion.*

*Caryatides.* Figures of women, which serve instead of columns to support the entablature.

*Casement.* The same as *Scotia*, which see. The term is also used for a sash hung upon hinges.

*Cauliculus.* The volute or twist under the flower in the Corinthian capital.

*Cavetto.* A hollow moulding, whose profile is a quadrant of a circle, principally used in cornices.

*Cell.* See *Naos.*

*Cincture.* A ring, list, or fillet, at the top or bottom of a column, serving to divide the shaft of the column from its capital and base.

*Chamfer*, (in Gothic architecture,) an arch, or jamb of a door, canted.

*Champ*, (in Gothic architecture,) a flat surface in a wall or pier, as distinguished from a moulding, shaft, or panel.

*Cinque-foil*, (in Gothic architecture,) an ornamental figure with five leaves or points.

*Column.* A member in architecture of a cylindrical form, consisting of a base, a shaft or body, and a capital. It differs from the pilaster, which is square on the plan. Columns should always stand perpendicularly.

*Composite Order.* One of the orders of architecture.

*Cope*, *Coping*, (in Gothic architecture,) the stone covering the top of a wall or parapet.

*Corbel*, (in Gothic architecture,) a kind of bracket. The term is generally used for a continued series of brackets on the exterior of a building, supporting a projecting battlement, which is called a *Corbel table.*

*Corinthian Order.* One of the orders of architecture.

*Cornice.* The projection consisting of several members which crowns or finishes an entablature, or the body or part to which it is annexed. The cornice used on a pedestal is called the cap of the pedestal.

*Corona* is that flat, square, and massy member of a cornice, more usually called the drip or larmier, whose situation is between the cymatium above, and the bed-moulding below. Its use is to carry the water, drop by drop, from the building.

*Corridor.* A gallery or open communication to the different apartments of a house.

*Corsa.* The name given by Vitruvius to a platband or square facia, whose height is more than its projecture.

*Crenelle*, (in Gothic architecture,) the opening of an embattled parapet.

*Crest*, (in Gothic architecture,) a crowning ornament of leaves running on the top of a screen, or other ornamental work.

*Crocket*, (in Gothic architecture,) an ornament of leaves running up the sides of a gable, or ornamented canopy.

*Cupola.* A small room, either circular or polygonal, standing on the top of a dome. By some it is called a lantern.

*Cushioned.* See *Frieze.*

*Cusp*, (in Gothic architecture,) a name for the segments of circles forming the trefoil, quatrefoil, &c.

*Cyma*, called also *Cymatium*, its name arising from its resemblance to a wave. A moulding which is hollow in its upper part, and swelling below.

*Decagon.* A plain figure, having ten sides and angles.

*Decastyle.* A building having ten columns in front.

*Decempeda.* (*Decem*, ten, and *pes*, foot, Lat.) A rod of ten feet used by the ancients in measuring. It was subdivided into twelve inches in each foot, and ten digits in each inch; like surveyors' rods used in measuring short distances, &c.

*Decimal Scale.* Scales of this kind are used by draftsmen, to regulate the dimensions of their drawings.

*Decoration.* Any thing that enriches or gives beauty and ornament to the orders of architecture.

*Demi-Metope.* The half a metope, which is found at the retiring or projecting angles of a Doric frieze.

*Dentils.* Small square blocks or projections used in the bed-mouldings of the cornices in the Ionic, Corinthian, Composite, and sometimes Doric orders.

*Details of an Edifice.* Drawings or delineations for the use of builders, otherwise called working plans.

*Diagonal Scale* is a scale subdivided into smaller parts by secondary intersections or oblique lines.

*Diameter.* The line in a circle passing from the circumference through the centre.

*Diamond.* A sharp instrument formed of that precious stone and used for cutting glass.

*Diapered* (in Gothic architecture). A panel, or other flat surface, sculptured with flowers, is said to be diapered.

*Diastyle.* That intercolumniation or space between columns, consisting of three diameters; — some say four diameters.

*Die*, or *Dye.* A naked, square cube. Thus the body of a pedestal, or that part between its base and cap, is called the die of the pedestal. Some call the abacus the die of the capital.

*Dimension.* (*Dimetier*, Lat.) In geometry is either length, breadth, or thickness.

*Diminution.* A term expressing the gradual decrease of thickness in the upper part of a column.

*Dipteral.* A term used by the ancients to express a temple with a double range of columns in each of its flanks.

*Dodecagon.* A regular polygon, with twelve equal sides and angles.

*Dodecastyle.* A building having twelve columns in front.

*Dome.* An arched or vaulted roof springing from a polygonal, circular, or elliptic plane.

*Doric Order.* One of the five orders of architecture.

*Dormant*, or *Dormer Window*, (in Gothic architecture,) a window set upon the slope of a roof or spire.

*Dooks.* Flat pieces of wood of the shape and size of a brick, inserted in brick walls, sometimes called plugs or wooden bricks.

*Door.* The gate or entrance of a house, or other building, or of an apartment in a house.

*Dormitory.* A sleeping-room.

*Drawing*, or *Withdrawing-Room.* A large and elegant apartment, into which the company withdraw after dinner.

*Dressing-Room.* An apartment contiguous to the sleeping-room, for the convenience of dressing.

*Drip*, (in Gothic architecture,) a moulding much resembling the cymatium of Roman architecture, and used for the same purpose as a canopy over the arch of a door or window.

*Drops.* See *Guttæ*.

*Echinus.* The same as the ovolo or quarter-round; but perhaps it is only called echinus with propriety.

*Edging.* The reducing the edges of ribs or rafters, that they may range together.

*Elbows of a Window.* The two panelled flanks, one under each shutter.

*Elevation.* A geometrical projection drawn on a plane, perpendicular to the horizon.

*Embankments* are artificial mounds of earth, stone, or other materials, made to confine rivers, canals, and reservoirs of water within their prescribed limits; also for levelling up of railroads, &c.

*Embrasure*, (in Gothic architecture,) the same as *Crenelle*, which see.

*Encarpus.* The festoons on a frieze, consisting of fruits, flowers, and leaves. See *Festoon*.

*Entablature.* The assemblage of parts supported by the column. It consists of three parts, the architrave, frieze, and cornice.

*Entail*, (in Gothic architecture,) delicate carving.

*Entasis.* The slight curvature of the shafts of ancient Grecian columns, particularly the Doric, which is scarcely perceptible, and beautifully graceful.

*Entresol.* See *Mezzanine*.

*Epistylum.* The same as *Architrave*, which see.

*Eustyle.* That intercolumniation, which, as its name would import, the ancients considered the most elegant, namely, two diameters and a quarter of a column. Vitruvius says this manner of arranging columns exceeds all others in strength, convenience, and beauty.

*Façade.* The face or front of any considerable building to a street, court, garden, or other place.

*Facia.* A flat member in the entablature or elsewhere, being in fact nothing more than a band or broad fillet.

*Fane*, *Phane*, *Vane*, (in Gothic architecture,) a plate of metal, usually cut into some fantastic form, and turning on a pivot, to determine the course of the wind.

*Fastigium*. See *Pediment*.

*Feather-edged Boards* are narrow boards made thin on one edge. They are used for the facings or boarding of wooden walls.

*Festoon*. An ornament of carved work, representing a wreath or garland of flowers or leaves, or both, interwoven with each other.

*Fillet*. The small, square member, which is placed above or below the various square or curved members in an order.

*Finial*, (in Gothic architecture,) the ornament, consisting usually of four crockets, which is employed to finish a pinnacle, gable, or canopy.

*Flank*. The least side of a pavilion, by which it is joined to the main building.

*Flatning*, in inside house-painting, is the mode of finishing without leaving a gloss on the surface, which is done by adding the spirits of turpentine to unboiled linseed oil.

*Flight of Stairs* is a series of steps, from one landing-place to another.

*Floors*. The bottom of rooms.

*Flutings*. The vertical channels on the shafts of columns, which are usually rounded at the top and bottom.

*Flyers* are steps in a series, which are parallel to each other.

*Folding-Doors* are made to meet each other from opposite jambs, on which they are hung.

*Foliage*. An ornamental distribution of leaves or flowers on various parts of the building.

*Foreshorten*. A term applicable to the drawings or designs in which, from the obliquity of the view, the object is represented as receding from the opposite side of the plane of the projection.

*Foundation*. That part of a building or wall which is below the surface of the ground.

*Foot*. A measure of twelve inches, each inch being three barleycorns.

*Frame*. The name given to the wood-work of windows, inclosing glass, and the outward work of doors or windows, or window-shutters, inclosing panels; and in carpentry, to the timber-work supporting floors, roofs, ceilings, or to the intersecting pieces of timbers forming partitions.

*Fret*. A kind of ornamental work, which is laid on a plane surface; the Greek fret is formed by a series of right angles or fillets, of various forms and figures.

*Frieze*, or *Frize*. The middle member of the entablature of an order, which separates the architrave and the cornice.

*Frontispiece*. The face or fore front of a house; but it is a term more usually applied to its decorated entrance.

*Front*. A name given to the principal interior façade of a building.

*Frustum*. A piece cut off from a regular figure; the frustum of a cone is the part that remains when the top is cut off by an intersection parallel to its base, as the Grecian Doric column without a base.

*Furrings* are flat pieces of timber, plank, or board, used by carpenters to bring dislocated work to a regular surface.

*Fust*. The shaft of a column. See *Shaft*.

*Gable*, (in Gothic architecture,) the triangularly-headed wall which covers the end of a roof.

*Gable Window*, (in Gothic architecture,) a window in a gable. These are generally the largest windows in the composition, frequently occupying nearly the whole space of the wall.

*Gablet*, (in Gothic architecture,) a little gable. See *Canopy*.

*Gauge*. In carpentry, an instrument to strike a line parallel to the straight side of any board or piece of stuff.

*Gain*. The bevelled shoulder of a binding joist.

*Garland*, (in Gothic architecture,) an ornamental band surrounding the top of a tower or spire.

*Glyphs*. The vertical channels sunk in the triglyphs of the Doric frieze.

*Gola*, or *Gula*. The same as *Ogee*, which see.

*Gorge*. The same as *Cavetto*, which see.

*Gouge*. A chisel of a semicircular form.

*Granite*. A genus of stone much used in building, composed chiefly of quartz, feldspar, and mica, forming rough and large masses of very great hardness.

*Groin*, (in Gothic architecture,) the diagonal line formed by the intersection of two vaults in a roof.

*Groined Ceiling*. A surface formed of three or more curved surfaces, so that every two may form a groin, all the groins terminating at one extremity in a common point.

*Groove*, or *Mortise*. The channel made by a joiner's plane in the edge of a moulding, stile, or rail, to receive the tenon.

*Ground Floor*. The lowest story of a building.

*Ground Plane*. A line forming the ground of a design or picture, which line is a tangent to the surface of the face of the globe.

*Ground Plot*. The ground on which a building is placed.

*Grounds*. Joiners give this name to narrow strips of wood put in walls to receive the laths and plastering.

*Guttæ*, or *Drops.* Those frusta of cones in the Doric entablature which occur in the architrave below the tænia under each triglyph.

*Gutters* are a kind of canals in the roofs of houses, to receive and carry off rain-water.

*Halving.* The junction of two pieces of timber, by inserting one into the other; in some cases to be preferred to mortising.

*Hand-railing.* The art of forming hand-rails round circular and elliptic well-holes without the use of the cylinder.

*Hanging-Stile of a Door* is that to which the hinges are fixed.

*Heel of a Rafter.* The end or foot that rests upon the wall-plate.

*Helical Line of a Hand-rail.* The line, or spiral line, representing the form of the hand-rail before it is moulded.

*Helix.* The curling stalk under the flower in the Corinthian capital. See *Cauliculus.*

*Hem.* The spiral projecting part of the Ionic capital.

*Hexastyle.* A building having six columns in front.

*Hood-mould* (in Gothic architecture). See *Drip.*

*Hook-pins.* The same as *Draw Bore-pins*, to keep the tenons in their place, while in the progress of framing; the pin has a head or notch in the outer end to draw it at pleasure.

*Hypæthral.* Open at top; uncovered by a roof.

*Hyperthyron.* The lintel of a doorway.

*Hypotrachelium.* A term given by Vitruvius to the slenderest part of the shaft of a column where it joins the capital. It signifies the part under the neck.

*Ichnography.* The transverse section of a building, which represents the circumference of the whole edifice; the different rooms and apartments, with the thickness of the walls; the dimensions and situation of the doors, windows, chimneys; the projection of columns, and every thing that could be seen in such a section, if really made in a building.

*Impost.* The layer of stone or wood that crowns a door-post or pier, and which supports the base line of an arch or arcade; it generally projects, and is sometimes formed of an assemblage of mouldings.

*Inch.* The twelfth part of a foot. For the purpose of reckoning in decimal fractions, it is divided into ten parts or integers.

*Inclined Plane.* One of the mechanical powers, used for raising ponderous bodies, in many instances of immense weight; a declivity of a hill, &c.

*Insular Column* is a column standing by itself.

*Insulated.* Detached from another building.

*Intaglio.* Any thing with figures in relief on it.

*Intercolumniation.* The distance between two columns.

*Intrados.* The under curved surface or soffit of an arch.

*Inverted Arches.* Such as have their intrados below the centre or axis.

*Ionic Order.* One of the orders of architecture.

*Jack Plane.* A plane about 18 inches long, to prepare for the trying plane.

*Jack Rafters.* The jack timbers, which are fastened to the hip rafters and the wall-plates.

*Jambs.* The side pieces of any opening in a wall, which bear the piece that discharges the superincumbent weight of such wall.

*Joinery*, in building, is confined to the nicer and more ornamental parts.

*Jointer.* A tool used for straightening and preparing stuff for joints, &c. This jointer is about two feet eight or ten inches long.

*Kerf.* The slit or cut in a piece of timber, or in a stone, by a saw.

*King Post.* The middle post in a section of rafters.

*Label*, (in Gothic architecture,) a name for the drip or hood-moulding of an arch when it is returned square.

*Lacunar*, or *Laquear.* The same as *Soffit.*

*Lantern*, (in Gothic architecture,) a turret or tower placed above a building, pierced either with windows to admit light, or holes to let out steam.

*Larmier.* Called also *Corona*, which see.

*Lath.* A narrow slip of wood $1\frac{1}{4}$ to $1\frac{1}{2}$ inches wide, $\frac{1}{4}$ to $\frac{3}{8}$ inch thick, and four feet long, used in plastering.

*Leaves.* Ornaments representing natural leaves. The ancients used two sorts of leaves, natural and imaginary. The natural were those of the laurel, palm, acanthus, and olive; but they took such liberties in the form of these, that they might almost be said to be imaginary, too.

*Level.* A surface which inclines to neither side.

*Lining.* Covering for the interior, as casing is covering the exterior surface of a building.

*Lintel.* A piece of timber or stone placed horizontally over a door, window, or other opening.

*List or Listel.* The same as fillet, or annulet.

*Listing.* The cutting the sap-wood out from both edges of a board.

*Loop*, (in Gothic architecture,) a small narrow window.

*Louvre* (in Gothic architecture). See *Lantern.*

*Luffer Boarding.* The same as blind slats.

*Machicolations*, (in Gothic architecture,) small openings in an embattled parapet, for the discharge of missile weapons upon the assailants. Frequently these openings are underneath the parapet, in which case the whole is brought forward and supported by corbels.

*Mechanical Carpentry.* That branch of carpentry which teaches the disposition of the timbers according to their relative strength, and the strains to which they are subjected.

*Mediæval Architecture.* The architecture of England, France, Germany, &c., during the Middle Ages, including the Norman and early Gothic styles.

*Members.* (*Membrum*, Lat.) The different parts of a building; the different parts of an entablature; the different mouldings of a cornice, &c.

*Metope.* The square space between two triglyphs of the Doric order. It is sometimes left plain, at other times decorated with sculpture.

*Mezzanine.* A low story introduced between two principal stories.

*Minerva Polias.* A Grecian temple at Athens.

*Minute.* The sixtieth part of the diameter of a column. It is the subdivision by which architects measure the small parts of an order.

*Mitre.* An angle of forty-five degrees, a half of a right angle.

*Modillion.* An ornament in the entablature of richer orders resembling a bracket.

*Module.* The semi-diameter of a column. This term is only properly used when speaking of the orders. As a semi-diameter it consists of only thirty minutes. See *Minute.*

*Mosaic.* A kind of painting representing cubes of glass, &c., and is formed of different colored stones, for paving, &c. Specimens of this kind have been found among the ruins of antiquity.

*Mouldings.* Those parts of an order which are shaped into various curved or square forms.

*Mouth.* The same as *Cavetto*, which see.

*Mutule.* A projecting ornament of the Doric cornice which occupies the place of the modillion in imitation of the ends of rafters.

*Mullion*, (in Gothic architecture,) the framework of a window.

*Naked.* The unornamented plain surface of a wall, column, or other part of a building.

*Naos*, or *Cella.* The part of a temple within the walls.

*Newel.* The solid, or imaginary solid, when the stairs are open in the centre, round which the steps are turned about.

*Niche.* A square or cylindrical cavity in a wall or other solid.

*Obelisk.* A tall, slender frustum of a pyramid, usually placed on a pedestal. The difference between an obelisk and a pyramid, independent of the former being only a portion of the latter, is, that it always has a small base in proportion to its height.

*Octastyle.* A building with eight columns in front.

*Ogee*, or *Ogive.* The same as *Cyma*, which see.

*Order.* An assemblage of parts, consisting of a base, shaft, capital, architrave, frieze, and cornice, whose several services, requiring some distinction in strength, have been contrived or designed in five several species, — Tuscan, Doric, Ionic, Corinthian, and Composite; each of which has its ornaments, as well as general fabric, proportioned to its strength and character.

*Ordonnance.* The arrangement of a design and the disposition of its several parts.

*Orle.* (Ital.) A fillet or band under the ovolo of the capital. Palladio applies the term also to the plinth of the base of a column or pedestal.

*Ovolo.* A moulding sometimes called a quarter-round, from its profile, being the quadrant of a circle. When sculptured it is called an *Echinus*, which see.

*Panel.* A thin board having all its edges inserted in the groove of a surrounding frame.

*Parapet.* From the Italian *parapetto*, breast-high. The defence round a terrace or roof of a building.

*Parastatæ.* Pilasters standing insulated.

*Pavilion.* A turret or small building generally insulated, and comprised beneath a single roof.

*Pedestal.* The substruction under a column or wall. A pedestal under a column consists of three parts, — the base, the die, and the cornice or cap.

*Pediment.* The low triangular crowning ornament of the front of a building, or of a door, window, or niche.

*Pend*, (in Gothic architecture,) a vaulted roof without groining.

*Pendant*, (in Gothic architecture,) a hanging ornament in highly enriched vaulted roofs.

*Pinnacle*, (in Gothic architecture,) a small spire.

*Peripteral.* A term used by the ancients to express a building encompassed by columns, forming, as it were, an aisle round the building.

*Peristylium.* In Greek and Roman houses, a court, square, or cloister.

*Perspective* is the science which teaches us to dispose the lines and shades of a picture so as to represent, on a plane, the image of objects exactly as they appear in nature.

*Piazza.* A continued arch-way, or vaulting, supported by pillars or columns ; a portico.

*Pier.* A solid between the doors or the windows of a building. The square or other formed mass or post to which a gate is hung.

*Pilaster.* A square pillar engaged in a wall.

*Pile.* A stake or beam of timbers, driven firmly into the ground.

*Pillar.* A column of irregular form, always disengaged, and always deviating from the proportions of the orders ; whence the distinction between a pillar and a column.

*Platband.* A square moulding, whose projection is less than its height or breadth.

*Plinth.* The square solid under the base of a column, pedestal, or wall.

*Porch.* An arched vestibule at the entrance of a church, or other building.

*Portico.* A place for walking under shelter, raised with arches in the manner of a gallery ; the portico is usually vaulted, but has sometimes a flat soffit or ceiling. This word is also used to denote the projection before a church or temple supported by columns.

*Post.* A piece of timber set erect in the earth. Perpendicular timbers of the wooden frame of a building.

*Posticum.* The back door of a temple ; also, the portico behind the temple.

*Principal Rafters.* The two inclined timbers which support the roof.

*Profile.* The contour of the different parts of an order.

*Projecture.* The prominence of the mouldings, and members beyond the naked surface of a column, wall, &c.

*Proscenium.* The front part of the stage of the ancient theatres, on which the actors performed.

*Prostyle.* A building or temple with columns in front only.

*Purlins.* Pieces of timber framed horizontally from the principal rafters to keep the common rafters from sinking in the middle.

*Pycnostyle.* An intercolumniation equal to one diameter and a half.

*Pyramid.* A solid with a square, polygonal, or triangular base, terminating in a point at top.

*Quarter-Round.* See *Ovolo* and *Echinus.*

*Quatrefoil,* (in Gothic architecture,) an ornament in tracery, consisting of four segments of circles, or cusps, within a circle.

*Quirk Mouldings.* The convex part of Grecian mouldings, when they recede at the top, forming a reënticent angle with the surface which covers the moulding.

*Quoins.* The external and internal angles of buildings or of their members. The corners.

*Radius,* in geometry, is the semi-diameter of a circle, or a right line drawn from the centre to the circumference ; in mechanics, the spoke of a wheel.

*Rails,* in framing, the pieces that lie horizontal ; and the perpendicular pieces are called stiles, in wainscoting, &c.

*Raking.* A term applied to mouldings whose arrises are inclined to the horizon.

*Relievo,* or *Relief.* The projecture of an architectural ornament.

*Resistance,* in mechanics, that power which acts in opposition to another, so as to diminish or destroy its effect.

*Reticulated Work.* That in which the courses are arranged in a net-like form. The stones are square, and placed lozengewise.

*Return.* (Fr.) The continuation of a moulding, projection, &c., in an opposite direction, as the flank of a portico, &c.

*Rib.* (Sax.) An arched piece of timber sustaining the plaster-work of a vault, &c.

*Ridge.* The top of the roof which rises to an acute angle.

*Ring.* A name sometimes given to the list, cincture, or fillet.

*Roman Order.* Another name for the Composite.

*Rose.* The representation of this flower is carved in the centre of each face of the abacus in the Corinthian capital, and is called the rose of that capital.

*Rustic.* The courses of stone or brick, in which the work is jagged out into an irregular surface. Also, work left rough without tooling.

*Sagging.* The bending of a body in the middle by its own weight, when suspended horizontally by each end.

*Salon.* An apartment for state, or for the reception of paintings, and usually running up through two stories of the house. It may be square, oblong, polygonal, or circular.

*Saloon.* (Fr.) A lofty hall, usually vaulted at the top, with two stages of windows.

*Sash.* The wooden frame which holds the glass in windows.

*Scaffold.* A frame of wood fixed to walls, for masons, plasterers, &c., to stand on.

*Scantling.* The name of a piece of timber, as of quartering for a partition, when under five inches square, or the rafter, purlin, or pole-plate of a roof.

*Scapus.* The same as *Shaft* of a column, which see.

*Scarfing.* The joining and bolting of two pieces of timber together transversely, so that the two appear but as one.

*Scotia.* The name of a hollowed moulding, principally used between the tori of the base of columns.

*Severy*, (in Gothic architecture,) a separate portion of a building.

*Shaft.* That part of a column which is between the base and capital. It is also called the Fust, as well as Trunk of a column.

*Shank.* A name given to the two intersticial spaces between the channels of the triglyph in the Doric frieze.

*Shooting.* Planing the edge of a board straight, and out of winding.

*Shoulder.* The plane, transverse to the length, of a piece of timber from which a tenon projects.

*Shutters.* The boards or wainscoting which shut up the aperture of a window.

*Sill.* The timber or stone at the foot of a window or door; the ground timbers of a frame which support the posts.

*Skirtings.* The narrow boards which form a plinth round the margin of a floor.

*Socle.* A square flat member, of greater breadth than height, usually the same as plinth.

*Soffit.* The ceiling or under side of a member in an order. It means, also, the under side of the larmier or corona in a cornice; also, the under side of that part of the architrave which does not rest on the columns. See also *Lacunar.*

*Sommer.* The lintel of a door, window, &c.; a beam tenoned into a girder, to support the ends of joists on both sides of it.

*Spandrel*, (in Gothic architecture,) the triangular space inclosed by one side of an arch, and two lines at right angles to each other, one horizontal, and on a level with the apex of the arch, the other perpendicular, and a continuation of the line of the jamb.

*Spiral.* A curve line of a circular kind, which in its progress recedes from its centre.

*Steps.* The degrees in ascending a staircase.

*Stereobata*, or *Stylobata.* The same as *Entasis.*

*Strap.* An iron plate, to secure the junction of two or more timbers, into which it is secured by bolts.

*Stretching Course.* Bricks or stones laid in a wall with their longest dimensions in the horizontal line.

*Surbase.* The mouldings immediately above the base of a room.

*Systyle.* An intercolumniation equal to two diameters.

*Table*, (in Gothic architecture,) any surface, or flat member.

*Tæni.* A term usually applied to the lastel above the architrave in the Doric order.

*Templet.* A mould used by bricklayers and masons for cutting or setting the work; a short piece of timber sometimes laid under a girder.

*Tenon.* A piece of timber the thickness of which is divided into about three parts; the two outside parts are cut away, leaving two shoulders, the middle part projects, and, being fitted to a mortise, is usually termed a tenon.

*Terrace Roofs.* Roofs which are flat at the top.

*Tetrastyle.* A building having four columns in front.

*Torus.* A moulding of semicircular profile, used in the bases of columns.

*Tracery*, (in Gothic architecture,) a term for the intersection, in various forms, of the mullions in the head of a window or screen.

*Transom*, (in Gothic architecture,) a cross mullion in a window.

*Trefoil*, (in Gothic architecture,) an ornament, consisting of three cusps in a circle.

*Triglyph.* The ornament of the frieze in the Doric order, consisting of two whole and two half channels, sunk triangularly on the plan.

*Trimens.* Pieces of timber framed at right angles with the joints against the wall, for chimneys, and well-holes for stairs.

*Trimmer.* A small beam, into which are framed the ends of several joists. The two joists into which each end of the trimmer is framed are called *trimming-joists.*

*Trough Gutter.* A gutter below the dripping eaves, to convey the water to the pipe by which it is discharged.

*Trunk.* See *Shaft.* When the word is applied to a pedestal it signifies the dado or die, or body of the pedestal answering to the shaft of the column.

*Truss.* When the girders are very long, or the weight the floors are destined to support is very considerable, they are *trussed.*

*Tuscan.* One of the orders of architecture.

*Tusk.* A bevel shoulder, made above a tenon, to strengthen it.

*Tympanum.* The space inclosed by the cornice of the sloping sides of a pediment, and the level fillet of the corona.

*Vault.* An arched roof so contrived that the stones or other materials of which it is composed support and keep each other in their places.

*Vestibule.* An ante-hall, lobby, or porch.

*Vice*, (in Gothic architecture,) a spiral staircase.

*Volute.* The scroll which is appended to the capital of the Ionic order.